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ABSTRACT

This bibliography lists books and articles discussing graphic aspects of human communication. References have been selected for their relevance to the design of self-instructional texts for the adult learner; for the most part, research on younger children, on non-text media, and on non-educational texts is not included. Items are organized into nine major headings, many of which have further subheadings: graphic communication, visual perception, visual instruction, quantitative data, diagrams, algorithms, typography, cartography, and notations, codes, and symbols. A list of 32 titles which are "recommended reading" is also included. (AA)

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Graphics in text: a bibliography

Michael Macdonald-Ross and Eleanor Smith

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Preface

This bibliography is a product of the Textual Communication Research Group. The information system we have built is funded by the Institute of Educational Technology, and I am grateful to the Director, Professor David Hawkridge, for his continued support and encouragement.

My chief debt is to Mrs Eleanor Smith, who has now worked with me for four years developing our information system. Her hard work and reliability has made a major contribution to the bibliography, and I am truly grateful to her. I am also grateful to Robert Waller for his help with the design and production of this bibliography.

The comments that precede each section are mine, and so is the responsibility for any mistakes or omissions. Any comments on the structure or content of the bibliography are welcome and may be addressed to me at the Institute.

Michael Macdonald-Ross
Institute of Educational Technology
March 1977

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Introduction

This bibliography deals with the graphic aspects of human communication. We do not here deal with ordinary language, which will be catered for next year in a separate publication. The two bibliographies are, in effect, a revised version of our original *Bibliography of Textual Communication* (1973).

This bibliography is by far the most extensive that has yet been produced on the graphic aspects of communication. Nevertheless, it has its limitations. Our information system is directed first of all to the needs of the Open University, and therefore we have collected references which might be relevant to the design of self-instructional texts for the adult learner. This means we generally do not list research on younger children, on non-text media and on non-educational texts. We do not list all the references if good reviews and textbooks exist in that particular subject; and we confine our attention mainly to works in English.

The classification system is, we think, a notable feature of this bibliography. It is in every respect more sophisticated and more useful than in the earlier bibliography, and the allocation of references to individual sections is more organised and reliable. Two countervailing principles are balanced in any system of categories. The first is: *do not conflate unlike entities.* The second is: *do not multiply categories unnecessarily.* Consider a classification as a filing cabinet: if too much stress is put on the first principle then every letter has a file of its own; if too much stress on the latter then all letters are filed under the same heading. This is the classic 'splitters and lumpers' problem of taxonomy. It goes without saying that no solution to such a balance can be optimal for all purposes, and no doubt readers will see the need for certain changes and additions. Nevertheless, we advise users to adopt the classification for their own use rather than try to build one *de novo.*

Friends gave us good advice, much of which we have not felt able to follow. We might have annotated each item: but that would certainly have meant employing a research assistant for two years working full-time on the project. In any event short descriptions are hopelessly misleading for most research cannot be taken at face value. We might have made the introductory comments into essay reviews so that busy persons could be spared the trouble of reading the original references; but my experience with *How numbers are shown* (a review of section 4) suggests that nothing short of a full-length textbook can do justice to the material in this bibliography.

There are some improvements in format since the original 1973 bibliography. The introductory essays are longer, and I have tried to identify the important works and key issues in that section. Some references are listed more than once to make retrieval simpler. This bibliography is more compact and legible than the previous edition. The date shown is the date of original publication (not 'Plato 1973') and the place of publication is given if the publisher is not based in London.

There are, in principle, two sources of reliable knowledge concerning the affairs of human beings and hence two kinds of publications that can be listed in a bibliography such as this. In the first place there is the tacit know-how of the practitioner: the accumulated experience of trial and error, the way of the craftsman which leads to the rare but important 'master performer'. And more recently we have the formal designed experiment with (supposedly) controlled variables and standard, replicated conditions. In our opinion both approaches can help to yield genuine knowledge, and therefore this bibliography lists both formal empirical tests and the testimony and the exemplars of master performers. We have been quite astonished to find that most experimental psychologists dismiss the experience of practitioners with scorn; and equally astonished to hear famous designers say that no experimental findings at all are of the slightest use to them. Perhaps one ought not to be so surprised considering the way people tend to adopt the systematised prejudices of the profession they join, and the rarity of critical thought and courage. At heart this question is one of epistemology, and cannot be tackled without a careful study of the history of ideas and the philosophy of science. Suffice it to say that no important philosopher or historian of recent years has adopted *either* of these extreme positions. Most (like Bunge, Polyani, Popper and

Toulmin) have held that practical experience, trial and error, theorising and formal experiments are connected together in rich and interesting ways in any fruitful science. Pursued by itself *neither* the designer's way nor the experimenter's way will yield a truly powerful science of instruction.

Readers are advised to use critical caution when using the research listed in this bibliography. It just will not do to take research results at face value – as I am afraid happens all too often. On the other hand the reader must not swing over to absolute despair and decide that nothing is known and hence he can dispense with the difficult task of sifting and weighing previous experience. A great deal is known, but there is no simple litmus-paper which will tell the reader 'at a glance' the difference between the phoney stuff and the real metal. Consequently, training instructional technologists is *not* primarily a matter of inculcating known facts. Rather, the task is to educate his powers of discrimination and so develop a fruitful approach to the practice of instruction.

1 Graphic communication: general

'To the scientific mind it is most annoying to have to deal with phenomena that cannot be formulated in a way that is satisfactory to intellect and logic.' *Jung*

So often graphic ideas cannot be exactly prescribed beforehand, nor their effect easily measured afterwards. This fact of life prevents any simple-minded empiricism from making progress; apparently some kind of preliminary sorting-out is necessary before we can proceed to a 'science of visual instruction'. Our work may as well start with the graphic devices themselves, for nothing can be 'tested for effectiveness' until it is first created – and that is exactly where many communicators fail. Self-instructional texts usually lack visual sophistication. In such a situation the first aim of applied research should not be technical – it should be inspirational: to open eyes and educate sensibility. Now, lest my empirical friends should sweep this aside with impatience, let me anticipate by remarking that the most frequent error made by researchers has been to disregard the subtleties of the stimulus material. A deep understanding of graphic devices is evidently a prerequisite to good experimental design.

Hogben's history of graphic communication is a fine introduction to our visual heritage. He really had a touch of genius; the illustrations in his books are imaginative, beautiful and functional. Modern self-instructional materials (working closely to whatever psychological prescriptions are fashionable) have rarely attained these standards. Evidently systematic prescriptions cannot be so strong as to substitute for a sensitive eye.

The recent discovery of the Madrid codex has caused quite a stir amongst Leonardo scholars. These notebooks contain technical drawings of even higher quality than the previous notebooks. Leonardo's methods were not mystical: they are displayed for us to see. He united inventive and technical mastery of the subject-matter with superb graphic skills. Some illustrators fail on *both* counts: they don't bother to grasp the subject and their visual imagination and graphic skill are unequal to the task. A 'systematic approach to visual instruction' will do little for a person in this situation, but a close look at da Vinci might.

Arnheim and Gombrich are art historians who have drawn connections between the psychology of perception and the act of interpreting works of art. They are great scholars who open doors, yet are wise enough not to offer prescriptions. Ivins is noteworthy for his striking (but not really well substantiated) theory of the growth of science. He believes that science depends on the exact replication of graphic images and therefore the invention of print was an essential precursor to the scientific revolution. I think this is too sweeping a claim to be carried merely by assertion; great revolutions are complex affairs not easily reduced to simple causes.

Arnheim R 1969
Visual thinking
Berkeley, U California Pr

Arnheim R 1975
Art and visual perception: the psychology of the creative eye 2nd ed
Faber

Banham R ed 1974
The Aspen papers: twenty years of design theory from the International Design Conference in Aspen
Pall Mall Pr

Briggs LJ 1970
Handbook of procedures for the design of instruction
Pittsburgh, American Institutes for Research

Brizio AM 1974
The Madrid notebooks: new aspects of Leonardo's genius emerge from his rediscovered manuscripts
Unesco Courier (Oct) 8-15

Brockman JM 1971
A history of visual communication
Tiranti

Brockman JM 1973
The graphic artist and his design problems 3rd ed
Academy Editions

Crane W 1896
Of the decorative illustration of books old and new
Bell

Crane W 1898
The bases of design
Bell

Davis A 1973
Graphics: design into production
Faber

Dondis DA 1974
A primer of visual literacy
Cambridge, Mass. MIT Pr

Garland K 1968
Graphics handbook
Studio Vista

Gessner R 1970
The moving image: a guide to cinematic literacy
New York, Dutton

Glaser M 1974
Graphics and design
Secker and Warburg

Gombrich EH 1962
Art and illusion: a study in the psychology of pictorial representation
Princeton U Pr

Gombrich EH 1971
Symbolic images
Phaidon Pr

Gombrich EH 1972
The 'what' and 'how': perspective representation and the phenomenal world
in Rudner R and Scheffler I eds
Logic and art: essays in honor of Nelson Goodman
New York, Bobbs-Merrill

Hamilton EA 1970
Graphic design for the computer age: visual communication for all media
New York, Van Nostrand

Hart IB 1963
The mechanical investigations of Leonardo da Vinci
U California Pr

Hess H 1974
Pictures as arguments
Sussex U Pr

Hofmann A 1970
Graphic design manual
Tiranti

Hogben L 1949
From cave painting to comic strip: a kaleidoscope of human communication
Parrish

Huggins WH 1971
Iconic communications
IEEE Trans on Ed E14:158-163

Hyman A 1973
The computer in design
Studio Vista

Ivins WM 1953
Prints and visual communication
Harvard U Pr

Karo J 1975
Graphic design: problems, methods and solutions
New York, Van Nostrand

Klee P 1961
The thinking eye
Lund Humphries

Kostelanetz R 1974
Moholy-Nagy
Allen Lane

Leonardo da Vinci
Selections from the notebooks ed IA Richter
Oxford U Pr 1952

Mead M and Modley R 1968
Communication among all people everywhere
Natural History (New York) Aug-Sept 56-63

Rand P 1966
Design and the play instinct
in Kepes G ed
The education of vision
New York, Braziller

Reti L 1971
Leonardo on bearings and gears
Scientific Am 224:100-110

Reti L 1974
The unknown Leonardo
New York, McGraw-Hill

Ross DW 1907
The theory of pure design, harmony, balance, rhythm
Boston, Houghton Mifflin

Rowland K 1973
A history of the modern movement in art and design
Rheinhold

Stankowski A 1967
Visual presentation of invisible processes
Tiranti

Waddington CH 1970
Behind appearances: a study of the relations between painting and natural sciences in this century
Edinburgh U Pr

2.1 Visual perception: general

'Percepts are guesses'. *Gregory*

If the notion of 'instructional psychology' has any validity then presumably the literature of visual perception can teach us something about graphic communication. But can it? That is, to say the least, an undecided question. Two extensive reviews set out to make the connection (Fleming and Travers) but the results are, in my opinion, not very impressive as aids to the practical communicator. It seems that the fundamentals of perception cannot be applied to the art of visual communication in any *simple* way. Therefore the references in this section may best be used as background education rather than vocational training.

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The state of cognitive psychology: a critical notice of Chase WG ed Visual information processing New York, Academic Pr
Q J Exp Psychol 27:141-152

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Visual thinking
Berkeley, U California Pr

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Art and visual perception: the psychology of the creative eye 2nd ed
Faber

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Some informational aspects of visual perception
Psychol Rev 61:183-193

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Geometric illusions as a function of pigmentation of the fundus oculi and target size
Psychonomic Sci 26:77-79

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Readings in perception
New York, Van Nostrand

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Visual selection: scanning vs filtering
Psychonomic Sci 3:561-562

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Perception and communication
Pergamon

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Academic Pr

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Conceptions of perceptual defense
Br J Psychol monograph supp 35

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Academic Pr

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How we see
in Chapanis A, Garner WR and Morgan CT eds
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New York, Wiley

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Visual information processing
Academic Pr

Corcoran DWJ 1971
Pattern recognition
Penguin

Dallett K and Wilcox S 1968
Remembering pictures versus remembering descriptions
Psychonomic Sci 11:139-140

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The individual eye: differences in visual perception
Crosby Lockwood Staples

Davies TN 1973
Visual perception of engineering drawings
Engineering Designer 4:22-31

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Sublimal perception: the nature of a controversy
New York, McGraw-Hill

Easterby RS 1969
The grammar of sign systems
Print 23:32-35,78,81

Fleming ML 1970
Perceptual principles for the design of instructional materials
Indiana U Bloomington AV Center

Foster JJ 1976
The influence of shape on apparent area: a new demonstration
Acta Psychol 40:103-113

Furby L 1972
The development of word perception and problem-solving strategies
Visible Language 6:45-58

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A theory of pictorial perception
AV Comm Rev 2:3-23

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Pictures, perspective and perception
Daedalus (winter) 216-7

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The senses considered as perceptual systems
Boston, Houghton Mifflin

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Principles of perceptual learning and development
New York, Appleton

Gombrich EH 1962
Art and illusion: a study in the psychology of pictorial representation
Princeton U Pr

Graham CH ed 1965
Vision and visual perception
New York, Wiley

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The intelligent eye
Weidenfeld and Nicolson

Gregory RL 1972
Eye and brain: the psychology of seeing 2nd ed
Weidenfeld and Nicolson

Gregory RL 1974
Concepts and mechanism of perception
Duckworth

Gregory RL and Gombrich EH eds 1973
Illusion in nature and art
Duckworth

Haber RN 1970
Contemporary theory and research in visual perception
New York, Holt Rinehart and Winston

Haber RN 1970
How we remember what we see
Scientific Am 222:104-112

Haber RN and Hershenson M 1973
The psychology of visual perception
New York, Holt Rinehart and Winston

Hinde RA 1972
Non-verbal communication
Cambridge U Pr

Hochberg J 1970
Attention in perception and reading
in Young FA and Lindsley eds
Early experience and visual information processing in perceptual and reading disorders
Washington, National Academy of Sciences pp 219-230

Hochberg J and Brooks V 1960
The psychophysics of form: reversible-perspective drawings of spatial objects
Am J Psychol 73:337-354

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Pictorial recognition as an unlearned ability: a study of one child's performance
Am J Psychol 75:624-628

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Vision, sign and inference
Visible Language 7:285-309

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On channel effectiveness
AV Comm Rev 16:245-267

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Output, error, equivocation and recalled information in auditory, visual and audio-visual information processing with constraint and noise
J Communication 18:325-353

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The informational capacity of the human eye
Science 113:292-293

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Subjective contours
Scientific Am 234:48-52

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Sight and mind: an introduction to visual perception
New York, Oxford U Pr

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A psychology of picture perception
Jossey-Bass

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Perceptual and action equivalence of photographs in children
Perceptual and Motor Skills 29:763-771

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Aspects of motion perception
Pergamon

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New York, Macmillan

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Human information processing
Academic Pr

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New York, Dover

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New York, Dover

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Brooks/Cole

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The wide angle reflective eye camera for visual choice and pupil size
Perception and Psychophysics 3:32-4

Mackworth NH and Morandi AJ 1967
The gaze selects informative details within pictures
Perception and Psychophysics 2:547-551

Miller LK 1973
Developmental differences in the field of view during covert and overt search
Child Devel 44:247-252

Morasky RM 1970
Time required to process information as a function of question placement
Am Ed Res J 7:561-567

Morasky RM 1972
Eye movement as a function of adjunct question placement
Am Ed Res J 9:251-261

Moray N 1970
Attention: selective processes in vision and hearing
Academic Pr

Mostofsky Di 1970
Attention: contemporary theory and analysis
New York, Appleton

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Visual search
Scientific Am 210:94-102

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Bell

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Imagery and verbal processes
New York, Holt Rinehart and Winston

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Improvement of visual and tactual form discrimination
J Exp Psychol 69:331-9

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The quantum theory of light and the psychophysiology of vision
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Psychology vol I:288-361
New York, McGraw-Hill

Pollack RH and Silvar S 1967
Magnitude of Muller-Lyer illusion in children as a function of pigmentation of the fundus oculi
Psychonomic Sci 8:83-84

Pollack I and Spencer D 1968
Subjective pictorial information and visual search
Perception and Psychophysics 3:41-44

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Canadian J Psychol 14:67-77

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The role of redundancy in discrimination of visual forms
J Exp Psychol 53:3-10

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The nature of perceptual adaptation
New York, Basic Books

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Berkeley, U California Pr

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Am J Psychol 69:60-69

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Recognition memory for words, sentences and pictures
J Verbal Learning and Verbal Behavior 6:156-163

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Man-machine systems: information, control and decision models of human performance
Cambridge, Mass. MIT Press

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Allen & Unwin

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Ergonomics 5:429-434

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Perception: selected readings in science and phenomenology
New York, Times Book Co

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Man's information system: a primer for media specialists and educational technologists
Scranton, Penn. Chandler

Vernon MD 1952
A further study of visual perception
Cambridge U Pr

Vernon MD 1962
The psychology of perception
Penguin

Vernon MD 1966
Experiments in visual perception: selected readings
Penguin

Vernon MD 1969
Visual perception and its relation to reading: an annotated bibliography
Newark, Delaware. International Reading Association

Vernon MD 1970
Perception through experience
Methuen

Wheelbarger JJ 1971
An investigation of the role of pictorial complexity in visual perception
Diss Abs Int 31(11)5864A

Wilman CW 1966
Seeing and perceiving
Pergamon

Young FA and Lindsley DB eds 1970
Early experience and visual information processing in perceptual and reading disorders
Washington, National Academy of Sciences

Zusne L 1970
Visual perception of form
Academic Pr

2.2 Colour perception

The use of colour in diagrams and illustrations is one of the old problems of visual instruction. Colour costs money and if used must be used well. But when should colour be used, and how should it be used? Anyone who thinks that a few simple empirical tests will yield reliable knowledge upon which prescriptions may be based is making a great mistake. Nothing in the whole of visual instruction is so difficult to master as the use of colour; nothing else shows so clearly the truth of all practical art – there are no universal prescriptions, just particular solutions. The one indispensible reference in this section is Albers, whose *Interaction of Colour* (original hardback edition) is one of the great masterpieces of practical tuition.

Albers J 1963
Interaction of color
New Haven, Yale U Pr

Allington R 1974
An evaluation of the use of color cues to focus attention in discrimination and paired-associate learning (abstract)
Reading Res Q 10:244-7

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The effects of color on the human organism
Am J Occup Therapy 13:125-129, 133

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New York, Van Nostrand

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New York, Wiley

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Colour in modern life: one man's colour
Royal Society of Arts J 112:145-152

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Colour in modern life: colour in the community
Royal Society of Arts J 112:167-173

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The effect of colored embellishments of a visual array on a simultaneously presented audio array
AV Comm Rev 13:159-164

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Visual discrimination of color normals and color deficients
AV Comm Rev 19:417-431

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The principles of harmony and contrast of colors
New York, Van Nostrand 1967

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Color and form in children's perceptual behavior
Perceptual and Motor Skills 18:313-316

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Code learning and color
J Psychol 58:295-299

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Functional and attention-getting effects of color on graphic communications
Perceptual and Motor Skills 31:851-854

Dwyer FM 1971
Color as an instructional variable
AV Comm Rev 19:399-416

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Student perception of the instructional effectiveness of black and white and color illustrations
J Exp Ed 40:28-34

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An introduction to color
New York, Wiley

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The perception of color
New York, Wiley

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Color and emotional arousal
Am Psychologist 13:340

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Theory of colors
Cambridge Mass. MIT Pr 1970

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Color coding in a visual search task
J Exp Psychol 51:19-24

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The experience of colour
New Society 30:904-905 (19 Nov)

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The elements of color
New York, Van Nostrand

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Br J Ed Psychol 35:21-27

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The instructional effectiveness of color in television: a review of the evidence
Stanford U/ERIC

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Teaching with color
J Engineering Ed 43:155-158

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New York, Van Nostrand

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The language of colour
New York, Dodd Mead

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A color notation
Boston, Ellis

Ostwald W 1931-33
Colour science
Winsor & Newton

Otto W and Askov E 1968
The role of color in learning and instruction
J Special Ed 2:155-165

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The perception of light and colour
Bell

Page A 1974
Colour in the use of visual aids
Visual Ed (Apr) 33-34

Poulton E B 1890
The colours of animals
Paul, Trench, Trubner

Rudisill M 1952
Children's preferences for color versus other qualities in illustrations
Elem Sch J 52:444-451

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The enjoyment and use of color r
New York, Peter Smith

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Human color perception: a critical study of the experimental foundation
New York, Elsevier

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A study of color in instructional materials and its effect upon learning
Diss Abs Int 31(8)3976A

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Color function in information perception and retention
Information Storage & Retrieval 9:257-265

Vickerstaff T 1964
Colour in modern life: Scientific aspects
Royal Society of Arts J 112:153-166

Wickler W 1968
Mimicry in plants and animals
Weidenfeld and Nicolson

2.3 Eye movements

If we wish to study the way students interpret visual material we must develop a suitable methodology. For many years 'pre and post' test designs have been used almost exclusively, with rather unimpressive results. Most questions of cognitive strategy need a record of *process*, an old principle recently revived by the new generation of psychologists. This leads one to consider what records might be available.

One behaviour which is always present is the movement of the subject's eyes. Other records can be added: verbal protocols, physiological measures, pre and post tests, constructive tasks ... but the linchpin is the record of eye movements. The chief reason eye movement studies went out of fashion was the difficulty of handling the records. Now computer processing of data is standard, and the need for records of process is more widely understood. Young and Sheena give a useful account of modern techniques, though researchers need to keep their eyes open for new wrinkles.

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A simple photographic method for continuously recording vertical and horizontal eye movements
Am J Optometry 32:88-92

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Eye movements accompanying daydreaming, visual imagery and thought suspension
J Abnormal and Social Psychol 69:244-252

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Eye movements as a complex indicator
J General Psychol 45:209-217

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The control of eye movements
Academic Pr

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Fixation errors in eye movements to peripheral stimuli
J Exp Psychol 75:444-446

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Visual search and stimulus orientation
Perceptual and Motor Skills 23:539-542

Buchsbaum M 1972
Individual differences in eye-movement patterns
Perceptual and Motor Skills 35:895-901

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Eye movements and the eye-hand span in typewriting
J Ed Psychol 23:104-121

Byford GH 1959
Eye movement recording
Nature 184:1493-1494

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Involuntary eye movements occurring during fixation effects of changes in target contrast
Am J Optometry 44:73-90

Carmichael L and Dearborn WF 1972
Reading and visual fatigue 2nd ed
Connecticut, Greenwood

Carver RP 1971
Pupil dilation and its relationship to information processing during reading and listening
J Appl Psychol 55:126-134

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2.4 Graphic displays

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2.5 Perception and culture

If, as Gibson supposed, seeing is 'by way of the rectilinear propagation of light' we seem to have a primarily passive, automated model of perception. In this case we expect individual and cultural differences to be minimal. On the other hand if (as Abercrombie, Gregory and others have argued) seeing is an hypothesis-testing act of interpretation we expect prior knowledge and experience to be extremely important. Of course, terms like 'seeing' and 'perception' are not univalent. Differentiating red from green is a physiological matter, and the ability is innate. Diagnosing an X-ray is quite another matter. Such extreme cases are, however, usually not chosen for inter-cultural tests. Most of these experiments have used perspective tests (especially those designed by Hudson). These tests have given a bewildering variety of results which do not allow any simple summary. It is certain that the ability to interpret perspective drawings is not innate, though once learnt it is retained with tenacity. This field of research is discussed by Deregowski in his excellent 1973 review.

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3.1 Visual instruction: general

'It is an art to get the full effect from pictures.' *Neurath*

The high fashion for general theories of visual instruction came in the mid-fifties just as the wartime impetus to instructional technology had begun to fade. Titles like *Towards a general model of communication* (Gerbner), *A theory of pictorial perception* (Gibson), *Why is a picture worth a thousand words?* (Gropper), *On the definition of 'picture'* (Knowlton), *Scientific principles for maximum learning from motion pictures* (Miller), *The scientific principles of textbook design and illustration* (Smith) are nothing if not ambitious: if scientific papers were subject to the Trade Descriptions Act some of these authors might be in danger of summonses for false description! In the twenty years since these 'theories' were constructed little of value has been built upon them. They seem to be sterile.

Perhaps no *general* theory of visual instruction will ever be possible, because communication is a practical human art and not an abstract science, and because the many different kinds of illustrations and diagrams are logically distinct and cannot be conflated. What is needed now is 'preliminary natural-history observation'. This penetrating insight occurs in a surprising place: page 113 of Miller's review! In one sense this bibliography is itself an example of 'natural history observation'. Algorithms, Isotype, nomograms ... these are imaginative functional solutions to particular problems. No general theory of visual communication was needed for their development, though each method does obey the logic of its own domain of application.

Since this bibliography is mainly concerned with the adult learner perhaps I may be permitted to sidestep the problems of general illustration. Those interested in children's books should look at the case of Little Red Riding Hood. This story has twice been rendered in pictorial form (Lavater and Earle); both versions are brilliant examples of graphic art. Lavater continues to create these visual stories which are so delightful and imaginative: such work owes nothing to academic psychology, and everything to what Klee called the 'thinking eye'.

The early empirical research on visual instruction is notable for the work on adult training films for the armed forces. This was part of the military training work done in the United States between 1942-1955 upon which the whole field of instructional technology is based. The debt we all owe to these outstanding workers is great indeed. Unfortunately, not much work was done on text materials – even though training and maintenance manuals are staple food to the armed forces. Those interested in exhuming training film research will find Allen an indispensible source. In his words: 'The studies supported by these [military] research programs tell us most of what we now know about the effectiveness and characteristics of AV communication'.

On the relation of words and pictures one should read Gombrich and Richards; they are in a class apart for their scholarship and breadth of vision. Otherwise this issue is best considered piecemeal by individual subject-matters, tasks, learners and types of diagram. There cannot be any general rule for deciding when to use a graphic device though there may be good solutions (or perhaps satisficing solutions) for particular cases. Incidentally, this explains why trait-treatment interaction and intermedia tests are so sterile. They operate above the crucial variables and tend to conflate unlike entities. Since when have we got reliable characterisations of learners? of stimulus materials? of interactions? Of course we have not got them. Therefore, piecemeal progress will be more fruitful than the testing of overarching hypotheses.

Scientific diagrams are discussed elsewhere (5.1) though Dwyer and Holliday are listed here for cross-reference. The reader may by now anticipate my comment: scientific diagrams are not illustrations of the general or decorative type. They are logically distinct, and indeed must be split down into many subtypes before any general statements could possibly be meaningful.

Macdonald-Ross and Waller put forward a thesis which is different from all others in this section. In their opinion practical communicators do not need any general theories. They need an

ethos to guide their everyday work. The Transformer is a humanist idea which, if taken seriously, would utterly change the production-line system whereby learning materials are produced in large organisations. When graphic illustrations fail it is usual to blame designers or artists for their incompetence and lack of interest in the subject-matter. But this is not a sufficient explanation. We have to ask ourselves: how is it that people can act with apparent disregard for the quality of their work? Surely because they have become separated from the natural feedback all of us must have, and (in desperation) substituted surrogate forms of gratification. In general, no-one can be a good communicator unless he lives with the consequences of his work (that is what 'being responsible' means).

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3.2 Comic strips

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Berkeley, U California Pr

Lupoff R and Thompson D 1971
All in color for a dime
New York, Ace Books

Lupoff R and Thompson D 1974
The comic-book book
New York, Arlington House

Murrell W 1938
History of American graphic humor
New York, Cooper Square

Orwell G 1940
Boys' weeklies
Horizon no 3
reprinted in Inside the whale and other essays
Penguin 1962

Perry G and Aldridge A 1971
The Penguin book of comics: a slight history
Allen Lane

Rackham N 1968
Comics vs education
New Ed 4:9-10 (Aug-Sep)

Rackham N 1968
A spoonful of sugar (comics)
New Ed 4:11-13 (Nov)

Reitberger RC and Fuchs WJ 1972
Comics: anatomy of a mass medium
Studio Vista

Robbins S 1970
Comics: the funnies and the weepies
Where 50 (July) 109-112

Robinson J 1974
The comics: an illustrated history
New York, Putnam

Schulz C 1972
Peanuts
New York, Rinehart

Shayer D 1975
'Warlords': images for the 70's?
Use of English 27:16-19

Sheridan M 1973
Classic comics and their creators
New York, Post

Sheridan M 1944
Comics and their creators: life stories of American cartoonists
New York, Luna Pr

Steranko J 1971
The Steranko history of the comics
New York, Crown

Tucker N 1970
Adolescent comics and magazines
Where 51 (Sep) 144-147

Tucker N 1970
Comics today
Where 47 (Jan) 7-10

Turner ES 1948
Boys will be boys: the story of Sweeney Todd, Deadwood Dick, Sexton Blake, Billy Bunter, Dick Barton et al
Joseph 3rd ed 1975

Waugh C 1947
The comics
New York, Luna Pr new ed 1974

Wertham F 1955
Seduction of the innocent: on the influence on children of 'horror comic' magazines
Museum Pr

White DM 1970
Comics
in Encyclopedia American v7:370-375

White DM and Abel RH 1963
The funnies: an American idiom
New York Free Pr

Zorbough HW ed 1944
Comics as an educational medium
J Ed Sociol 18:193-255

4.1 Quantitative data: general

'If it can't be counted, it isn't science' *Lord Kelvin*
'All social facts are statistical' *Otto Neurath*

Counting has taken on a new importance since the scientific/industrial revolution – a fact well captured by the two quotations at the head of this section. Although it might be hard to find anyone today who would make such extreme claims, nevertheless we are still all creatures of the same era. The adequate presentation of social and technical data is essential to our world.

Numerical data can be presented in many formats: as tables, graphs, bar charts, Isotype charts, nomograms ... Practising communicators have always felt that some of these formats must be more effective than others, or at any rate they feel the choice does make some kind of difference. They are right: it does make a difference. However, no one format is universally superior. Each has its domain of application which must be understood and respected. It is no good using a complex table if you wish to show trends to the general public; and it is no use offering an engineer an Isotype chart instead of a nomogram.

To choose a suitable format is not enough; one must be able to execute that format competently. The skill needed to produce good charts or tables is considerable, and anyone who underestimates this will pay a heavy penalty. Researchers have often spoilt their work by using poor stimulus material, and then their laboriously produced results cannot be used. Practical communicators produce many charts and tables which simply cannot be decoded by the reader – not because the reader is ignorant or stupid but because the designer has just not mastered the skills required by the chosen format. When we use prose we know that the responsibility for communicating to an interested reader lies primarily with us. We are responsible. Our artistry must be adequate so the prose can be understood by readers of a particular kind. But our ignorance of graphic artistry often leads us to project our incompetence onto the reader. The reader is responsible for the act of interpretation – wrestling with the ideas – and he can well do without gratuitous obstacles being added to this task.

There are two major reviews which can be recommended (Funkhouser 1937; Macdonald-Ross 1977) – indeed, they are prescribed reading for anyone intending experimental or practical work in this field. Funkhouser's historical survey is a marvellous piece of scholarship which puts the origin and development of the various formats in context. New graphic formats are invented to meet specific practical needs which could not be satisfied by existing means. Then follows a period of evolution: a piecemeal, erratic progression by the 'master performers' of the day.

Macdonald-Ross (1977) looks in detail at the empirical research. He divides formats into two classes: those used to present general trends and comparisons, and those used to present exact numbers. He concludes that the advice given by the best practical communicators (the master performers) has been substantially vindicated by empirical research. One or two workers quite openly suggested that such advice was just 'a matter of opinion' and hence as likely to be wrong as right, but their scepticism has not proved justified. On the contrary, where researchers fail, they fail because they use substandard stimulus material or inappropriate task criteria. This comes about because they do not know enough about the *art* required to design good charts. The word 'art' is used deliberately to suggest a skill developed through practice and embodying tacit knowledge. Any researcher who underestimates this is almost bound to come up with a poor experimental design and, unhappily, quite a few have. But despite all these difficulties some useful knowledge has accumulated: in this review Macdonald-Ross lists forty conclusions which seem reliable and worth the attention of communicators.

There are still many questions that await attention. We know little or nothing about the cognitive strategies used by readers during the process of interpretation; and we know little about the effect of the trade-offs that take place during the process of designing a chart. Master performers

need to be studied, and the systematic collection and analysis of subject's errors should become standard procedure. Research in this area cannot be easy, because good models are lacking; but it can be rewarding because the problems are interesting and important.

In addition to the reviews by Funkhouser and Macdonald-Ross, this section lists some general texts. There is no really good modern textbook; Brinton, Karsten and Modley were landmarks in their day, and are still worth looking at. Ehrenberg, Tukey and Zeisel are good but not comprehensive. Bachi and Bertin are over-complicated (accurate construction does not guarantee accurate perception). Some of the works listed here, such as McHale and Sillitoe and *Facts in focus* are collections of examples. These examples are attempts to make social statistics more available, usually by governments or national organisations. The graphic standard of these sources is generally mediocre; apparently the gap between the master performers and the routine illustrator/designer is vast. The modern enthusiasm for paper qualifications has done little for the on-the-job effectiveness of the illustrator – but knowing the reality of curriculum design this is maybe just what one might expect.

Anderson E 1957
A semigraphical method for the analysis of complex problems
Proceedings National Academy of Science 13:923-927
reprinted in Technometrics 2:387-391, 1960

Bachi R 1968
Graphical rational patterns: a new approach to graphical presentation of statistics
Jerusalem, Israel U Pr

Bertin J 1967
Semiologie graphique: les diagrammes, les reseaux, les cartes 2nd ed 1973
Paris, Mouton Gauthier Villars

Biderman AD 1971
Kinostatistics for social indicators
Educational Broadcasting Rev (Oct) 13-3

Brinton WC 1916
Graphic methods of presenting facts
New York, Engineering Magazine
rep Norwood Editions, Pennsylvania

Carroll P 1960
How to chart data
New York, McGraw-Hill

Chalmers CC 1970
A clinician looks at the role of statistics in clinical research
Symposium on Statistical Aspects of Protocol Design 9-10 Dec (National Cancer Institute)
San Juan pp5-12

Chriss M and Hayes GR 1964
Introduction to charts and their use
Glasgow, Brown, Son & Ferguson

Clarke JI 1959
Statistical map-reading
Geography 44:96-104

Croxton FE 1927
Further studies in the graphic use of circles and bars
J Am Stat Assoc 22:36-39

Croxton FE and Stein H 1932
Graphic comparison by bars, squares, circles and cubes
J Am Stat Assoc 27:54-60

Croxton FE and Stryker RE 1927
Bar charts versus circle diagrams
J Am Stat Assoc 22:473-482

Culbertson HM and Powers RD 1959
A study of graph comprehension difficulties
AV Comm Rev 7:97-110

Culbertson H, Flores T, Powers R and Sarbaugh IF 1959
Using graphs more effectively for economic information
U Wisconsin Agricultural Journalism Department Bulletin 29

Davis P 1974
Data description and presentation
Oxford U Pr

Eells WC 1926
The relative merits of circles and bars for representing component parts
J Am Stat Assoc 21:119-132

Ehrenberg ASC 1975
Data reduction: analysing and interpreting statistical data
New York, Wiley

Ekman G and Junge K 1961
Psychophysical relations in visual perception of lengths, area and volume
Scand J Psychol 2:1-10

Feliciano GD, Powers RD and Kearl BE 1962
Text, table or graphs for communicating statistical information
U Wisconsin Agricultural Journalism Department Bulletin 32

Feliciano GD, Powers RD and Kearl BE 1963
The presentation of statistical information
AV Comm Rev 11:32-39

Flannery JJ 1956
The graduated circle: a descriptive analysis and evaluation of a quantitative map symbol
PhD diss U Wisconsin Univ Microfilms 00-19085

Flannery JJ 1971
The relative effectiveness of some common graduated point symbols in the presentation of quantitative data
Canadian Cartographer 8:96-109

Funkhouser HG 1937
Historical development of the graphical representation of statistical data
Osiris 3:269-404

Great Britain Central Statistical Office 1974
Facts in focus 2nd ed
Penguin Books with HMSO

Great Britain Prime Minister's Office 1944
Statistics relating to the war effort of the United Kingdom
Cmd 6564

Halley E 1693
An estimate of the degree of the mortality of mankind
Assurance Magazine 18:251-265 1874
rep from Philosophical Trans 17:579 no 196

Harper WM 1965
Statistics
Macdonald and Evans

Huff D 1967
How to lie with statistics
Gollancz

Karsten KG 1923
Charts and graphs: an introduction to graphic methods in the control and analysis of statistics
New York, Prentice-Hall

Kendall MG and Buckland WR 1975 (3rd ed)
A dictionary of statistical terms
Oliver & Boyd

Kruskal W 1976
Visions of maps and graphs
U Chicago Dept of Statistics
Technical report 18

Lutz RR 1949
Graphic presentation simplified
New York, Funk and Wagnalls

Macdonald-Ross M (1977)
How numbers are shown: a review of research on the presentation of quantitative data
Open U, Institute of Ed Tech
to be published in AV Comm Rev

McHale J 1972
World facts and trends 2nd ed
New York, Macmillan

Modley R 1937
How to use pictorial statistics
New York, Harper

Moroney MJ 1951
Facts from figures
Penguin

Peterson LV and Schramm W 1955
How accurately are different kinds of graphs read?
AV Comm Rev 2:178-189

Redwood H 1974
Mind your own business: how to succeed in business with charts
Leviathan House books

Richardson JB 1975
The automation of fishing charts at the White Fish Authority
Cartographic J 12:123-127

Schmid CF 1954
Handbook of graphic presentation
New York, Ronald

Sillitoe AF 1973
Britain in figures: a handbook of social statistics
2nd ed
Penguin

Spear ME 1952
Charting statistics
New York, McGraw-Hill

Tukey JW 1976
Exploratory data analysis
Reading, Mass. Addison-Wesley

Vernon MD 1946
Learning from graphical material
Br J Psychol 36:145-158

Vernon MD 1950
The visual presentation of factual material
Br J Ed Psychol 20:174-185

Vernon MD 1951
Learning and understanding
Q J Exp Psychol 3:19-23

Vernon MD 1952
The use and value of graphical material in presenting quantitative data
Occup Psychol 26:22-34

Vernon MD 1952
The use and value of graphical materials with a written text
Occup Psychol 26:96-100

Vernon MD 1953
Presenting information in diagrams
AV Comm Rev 1:147-158

Von Huhn R 1927
Further studies in graphic use of circles and bars: a discussion of the Eells experiment
J Am Stat Assoc 22:31-36

Washburne JN 1927
An experimental study of various graphic, tabular and textual methods of presenting quantitative material
J Ed Psychol 18:361-376 and 465-476

Wolfe ML and Martuza VR 1976
The effect of format and organization on extrapolation and interpolation with multiple trend displays
Paper presented at Annual meeting AERA
San Francisco, California 23 April 1976

Wright P 1977
Presenting technical information: a survey of research findings
to be published in Instructional Science

Zeisel H 1968
Say it with figures 5th rev ed
New York, Harper

4.2 Isotype

Otto Neurath's Isotype system is one of the great graphic inventions of the century. The system consists of a set of principles and procedures for transforming statistical data into pictorial charts. The writings of Neurath give only the barest idea of the full scope of the system, so one needs to look closely at the charts themselves: *Gesellschaft unt Wirtschaft* and *Modern Man in the Making* are beautiful sources that are worth many hours of study. The records of the Isotype Institute have been donated to the University of Reading library (Berkshire, England) where they may be examined by accredited scholars.

There is a tendency for empirical researchers to underestimate the importance of personal skills developed by practice and experience. Although (as Polanyi has shown) scientific knowledge has its roots in the tacit, nevertheless experimental psychologists often come to think that their controlled experiments are the only route to reliable knowledge. Therefore they tend to discount the art of the skilled practitioner, and may come to conduct experiments on substandard stimulus material. Supposing a poorly-designed chart fails to communicate. What conclusions can be drawn? None. Washburne and Vernon both conducted experiments on pictorial charts with extremely poor stimulus material. It comes as no surprise to discover that subjects couldn't get much from the charts. How could they? One can hardly blame the graphic method or the subjects for the experimenter's incompetence, yet Vernon does just this! Sadly, defects of this kind throw doubt on all Vernon's work on learning from 'graphical material' (listed in previous section).

Faithfull G 1931
Picture statistics
New Era 12:280-281

Hood P 1945
Pictorial statistics and diagrams
Penrose Annual 38:67-69

Koberstein H 1973
Statistik in bildern
Stuttgart, Poeschel

Language of Isotype
New York Times section 11 Jan 17 1937

Modley R 1937
How to use pictorial statistics
New York, Harper

Modley R and Lowenstein D 1952
Pictographs and graphs: how to make and use them
New York, Harper

Neurath M 1960
The origin and theory of Isotype
Yearbook of Education

Neurath M 1965
Living with one another
Macdonald

Neurath M 1971
Otto Neurath and Isotype
Graphic Design (Japan)

Neurath M 1974
Isotype
Instructional Science 3:127-150

Neurath O 1929
Die Bunte Welt: Mengebilder fur die Jugend
Vienna, Wolf

Neurath O 1930
Gesellschaft und Wirtschaft: Bildstatistisches Elementarwerk des Gesellschafts und Wirtschafts-museums in Wien
Leipzig, Bibliographisches Institut

Neurath O 1932
Technik und Menscheit
Wien-Leipzig, Deutscher Verlag fur Jugend und Volk

Neurath O 1936
International picture language
Kegan Paul

Neurath O 1937
Basic by Isotype
Kegan Paul

Neurath O 1937
Visual representation of architectural problems
Architectural Record 57-61

Neurath O 1939
Modern man in the making
Secker & Warburg; and New York, Knopf

Neurath O 1944
The human approach to visual education
Health Ed J 2:61-66

Neurath O 1944
Visual aids and arguing
New Era 25:51-61

Priestley E 1933
The Vienna picture statistics
New Era 14:169-172

Reading University 1975
Graphic communication through Isotype
Published in connection with an exhibition recording the 50th anniversary of the Gesellschafts-und Wirtschaftsmuseum in Wien held in the library of the U of Reading, May to Oct 1975

Schwarzman ME 1934
The Neurath pictorial statistics
Progressive Education 11:211-221

Statistics for the young
Times Ed Supp 27 Jan 1934

Tschichold J 1931
Statistics in pictures, a new method of presenting facts
Commercial Art 11:113-117

Twyman M 1976
The significance of Isotype
Icographic 10:3-10

Washburne JN 1927
An experimental study of various graphic, tabular and textual methods of presenting quantitative material. Parts I and II
J Ed Psychol 18:465-76 and 465-76

Wrightsone JW 1936
Conventional versus pictorial graphs
Progressive Ed 13:460-462

4.3 Graphs

Although interpreting graphs is a daily activity for working scientists there is little or no empirical research on their design and use. MacPherson and Jones can be recommended as a source-book for graphs in physics – the science which most closely conforms to Kelvin's prescription. Graphs which are used as abacs are treated under Nomograms.

Funkhouser HG 1937
A note on a tenth century graph
Osiris 1:260-262

Graham J 1937
Illusory trends in the observation of bar graphs
J Exp Psychol 20:597-608

Joint Committee on Standards for graphic presentation 1915
Preliminary report published for the purpose of inviting suggestions for the benefit of the committee
J Am Statistical Assoc 14:790-798

MacPherson IS and Jones BR 1974
The interpretation of graphs in physics
Hutchinson

Price JR, Martuza VR and Crouse JH 1974
Construct validity of test items measuring acquisition of information from line graphs
J Ed Psychol 66:152-156

Schutz HG 1961
An evaluation of formats for graphic trend displays
Human Factors 3:99-107

Schutz HG 1961
An evaluation of methods for presentation of graphic multiple trends
Human Factors 3:108-119

Weintraub S 1967
What research says to the reading teacher: reading graphs, charts and diagrams
Reading Teacher 20:345-349

4.4 Tables

The design and setting of tables is an arcane art which few have understood well. Primary source data from social surveys is usually presented in tabular form, so tables are one of the basic formats for presenting quantitative data. They combine two useful benefits (exact numbers and economy of space); their weakness is their abstract nature. Even educated people need time to get the main

points from a table (much more time than they would need with a bar chart or pictorial chart) and less sophisticated people often cannot use tables at all. Thus the choice of a table involves a complex trade-off between compactness, exactness and ease of usage.

The experiments by Wright on decimal currency tables brought out the difference between *explicit* tables (where the information can be read directly) and *implicit* tables (where the user must extrapolate or add figures to get the solution): implicit tables seemed to 'buy economy of space at the cost of comprehension'.

Ehrenbergs paper on numeracy is first-class; so are the books by Ehrenberg, Tukey and Zeisel listed in section 4.1.

Carter LF 1946
The relative effectiveness of presenting numerical data by the use of tables and graphs
HQ Air Material Command Engineering Division
Memorandum report No TSEAA 694-1 April 17

Carter LF 1946
A study of the best design of tables and graphs for presenting numerical data
Memorandum report No TSEAA 694-4C
Aero Medical Laboratory Engineering Division
USAF Wright Patterson Air Force Base Dayton Ohio

Carter LF 1947
An experiment on the design of tables and graphs used for presenting numerical data
J Appl Psychol 31:640-650

Deming HG 1917
The graphical interpolation of tabulated data
Am Chemical Society J 39:2388-2392

Ehrenberg ASC (in press)
Rudiments of numeracy
J Royal Stat Soc

Fisher GH 1965
The new form statistical tables
U London Pr

Hartley J and Young M 1975
On the typing of tables
Appl Ergonomics 6:39-42

Tinker MA 1954
Readability of mathematical tables
J Appl Psychol 38:436-442

Tinker MA 1960
Legibility of mathematical tables
J Appl Psychol 44:83-87

Wright P 1968
Using tabulated information
Ergonomics 11:331-343

Wright P 1972
Explicit and implicit tabulation formats
Ergonomics 15:175-187

Wright P 1973
Understanding tabular displays
in The visual presentation of technical data
ERS/SIAD University of Reading Typography Unit

Wright P and Barnard PJ 1975
Effects of 'more then' and 'less than' decisions on the use of numerical tables
J Appl Psychol 60:606-611

Wright P and Fox K 1970
Presenting information in tables
Appl Ergonomics 1:234-242

4.5 Nomograms

A nomogram is a graphic representation of an equation on a plane surface. They were invented in the last century by engineers as a source of data for design purposes. Abacs are nomograms drawn on Cartesian co-ordinates; alignment charts are composed of three or more scales arranged so that a line joining two known values cuts the third scale to show the required value. It is widely believed that alignment charts are much superior to abacs and (though there is little formal published evidence) it is wise to respect the views of expert practitioners. Doubtless many informal tests have been conducted behind the scenes. The alignment chart was systematised by the great d'Ocagne and ranks as a graphic invention as important for engineering data as Isotype is for social data.

The work by Beeby and Taylor is a welcome example of good experimental technique. They describe the formative evaluation of an abac using the collection and analysis of errors as the key

technique. The experiments of Carter remind us that the chief rival to the nomogram is the table. The choice between these formats involves a complex trade-off between cost, space, convenience, accuracy and speed. These trade-off situations provide one good reason why the search for universal general solutions to the problems of graphic communication will never be realised. Of course, there may be good methods for particular cases.

Adams DP 1950
An index of nomograms
New York, Wiley

Adams DP 1964
Nomography: theory and applications
Hamden, Connecticut. Shoe String Pr

Allcock HJ and Jones JR 1950
The nomogram 4th ed
Pitman

Beeby AW and Taylor HPJ 1973
How well can we use graphs?
Communicator of Scientific & Technical Information 17:7-11

Carter LF 1946
The relative effectiveness of presenting numerical data by the use of tables and graphs
HQ Air Material Command Engineering Division
Memo report no TSEAA 694-1 April 17

Carter LF 1946
A study of the best design of tables and graphs used for presenting numerical data
Aero Medical Laboratory Equipment Division
USAF Wright-Patterson Air Force Base Dayton Ohio
Memo report no TSEAA 694-1C

Carter LF 1947
An experiment on the design of tables and graphs used for presenting numerical data
J Appl Psychol 31:640-650

Cureton EE and Dunlap JW 1929
A nomograph for estimating the reliability of a test in one range of talent when its reliability is known in another range
J Ed Psychol 20:537-538

Davis DS 1960
Chemical processing nomographs
New York, Chemical Pubs

Davis DS 1962
Nomographs and empirical equations 2nd ed
New York, Van Nostrand

D'Ocagne M 1921
Trait de nomographie 1st ed 1899
Paris, Gauthier-Villars

Douglass RD 1970
Nomograph
McGraw-Hill Encyclopedia of Science & Technology

Douglass RD and Adams DP 1947
Elements of nomographs
New York, McGraw-Hill

Ford LR 1944
Alignment charts
Notre Dame, Ind

Ford LR 1969
Nomography
Encyclopaedia Britannica

Griffin HD 1930
Nomograms for checking the reliability of test scores
J Appl Psychol 14:609-611

Griffin HD 1932
How to construct nomograms
J Ed Psychol 23:561-577

Johnson LH 1952
Nomography and empirical equations
New York, Wiley

Levens AS 1959
Nomography 2nd ed
Belmont, California. Fearon

Martin R 1968
Cours de nomographie 6th ed
Paris, Eyrolles

Moffat DW 1965
Charts and nomographs for electronic technicians and engineers
Pennsylvania, TAB Books

Rulon PJ 1930
A graph for estimating reliability in one range knowing it in another
J Ed Psychol 21:140-142

Schilling F 1900
Uber die Nomographie von M d'Ocagne
Leipzig, Teubner

Schutz HG 1961
An evaluation of formats for graphic trend displays
Human Factors 3:99-107

Schutz HG 1961
An evaluation of methods for presentation of graphic multiple trends
Human Factors 3:108-119

Yule GU 1927
On reading a scale
J Royal Statistical Society 90:570-587

5.1 Scientific and mathematical diagrams

'Technical illustration is a medium for imparting information ... that is, the psychology of seeing as distinct from the principles of projection' *Booker*

Scientists and technologists are remarkably inventive in their use of diagrams; these diagrams are not just 'illustrations' but essential tools of thought and communication. Without them there would scarcely be any science and technology – it is as simple as that. There are so many kinds of diagram and so many subtle differences in use and function that, very likely, no other general statement can be made. All detailed knowledge must deal with particular types and particular uses – an obvious point, were it not so often forgotten. To develop this detailed understanding we need historical studies, conceptual analysis, taxonomic proposals and evidence of usage: in short, we need the kind of natural history which has preceded the growth of all the sciences. If there ever is to be a science of instruction it cannot leap into existence fully grown. Useful and interesting empirical tests are dependent on this ground-clearing scholarship.

As a matter of fact working scientists have almost never conducted experiments on their own diagrams: they seem mostly to use diagrams without being aware of what it is they are doing. The diagrams evolve by trial and error and consensus without any formal design and with perfectly satisfactory results: the typical growth pattern of craft knowledge. The gradual articulation of this tacit know-how is, of course, one crucial aim of the natural history approach. Mathematical and scientific diagrams display relationships which are part of the discourse, but which do not necessarily require the reader to undertake operational tasks. In the next section we deal with operational diagrams that instruct or aid the reader while he performs well-specified tasks. This distinction is needed because the function of a scientific diagram cannot be reduced to a prespecified list of behaviours and so conflated with genuine task-based diagrams. The latter are justified by a process of task analysis that cannot in any real sense be operated on the former.

Einstein said 'if you want to understand scientists, look at what they do'. There is certainly no other way to understand the diagrams scientists use, for the know-how they embody is largely tacit (not articulated). Nevertheless, these diagrams are strongly rule-bound, that is, the manner of construction and interpretation is not arbitrary but codified. In a little-known elementary text Patrick Meredith made these points:

> 'One of the factors which makes graphic organisation so powerful is that it can draw simultaneously on a number of different codes and so achieve great economy of expression. It is profitable to examine a number of charts and diagrams in some detail in order to understand their symbolism. Some codes are more obvious than others. Some are so little obvious as to be invisible. The most important example of this tacit symbolism is the relative position of elements in a diagram.' (Meredith 1961).

Meredith goes on to illustrate his theme by analysing ten diagrams, including the famous Mendeleev table which is (as he rightly says) 'one of the most remarkable instances of graphic organisation of knowledge in the whole history of science.'

Toulmin has been the only major historian of science to look at the role diagrams play in the growth and spread of ideas. In his elementary text he discusses the role of geometric diagrams in the development of optics:

> 'We are faced here with *a novel method of drawing physical inferences* – one which the writers of books on logic have not recognised for what it is ... in geometrical optics one learns to draw inferences, not in verbal terms, but by drawing lines ... This diagram plays a logically indispensable part of the physicist's explanation.' (Toulmin 1953).

Scientific diagrams are not just illustrations; they are as much part of the subject-matter as are the technical terms, apparatus, formulae, methods and other intellectual devices used to manipulate and explain the objects of investigation. Much the same can be said of mathematical diagrams;

indeed the diagrams used for geometry and trigonometry are one of the most ancient forms of graphic communication. During his lifetime Hogben was a leader in the art of graphic communication and it is still interesting to see how he used mathematical diagrams. Two of his best works are listed below; few modern educational texts bear any comparison with them. It is a common armchair criticism of visual texts that the author has debased the subject for the sake of show. Hogben never did; his popular works (like those of Neurath) were based on deep understanding of the subject-matter.

Dwyer's series of experiments on diagrams of the heart are the only extensive empirical studies reported in the literature. Interpreting these experiments is not a simple matter, and there is no space here to dissect them in detail. Nevertheless, some comments must be made, for to accept the experiments entirely at face value (as some have done) really does no service to the development of instructional technology.

The stimulus material (Dwyer 1972) is below the standard of good medical illustration; the line drawing is primitive and the use of colour is distinctly poor. Proper use of photographs, line drawing and colour are exhibited in most major textbooks of anatomy (such as, Gray's *Anatomy);* and it is clear that good illustrators use different techniques to achieve different ends. So what can be the point of testing different methods against the same criteria? Diagrams are used for many purposes; what one needs is the right illustration in each particular case. We see here the difficulty caused by posing experimental questions which are too general or universal. This leads to the next doubt: the learner tasks as measured by Dwyer's criterion test. This test does not cover surgical manipulation or dissection; it is mainly rote-recall of names and technical terms. It is reasonable to suppose that the line drawings would perform well under such criteria; equally it would not be difficult to devise performance measures which could hardly be attempted wth Dwyer's stimulus material. None of this is in dispute; surely there is no one best diagram, only good diagrams for particular purposes. The 'realism continuum' – the theoretical basis for all Dwyer's experiments – seems hardly appropriate for this kind of educational material. Meredith discusses a diagram of the circulation of the blood in these terms: 'It makes no attempt at realism because the object is not to show what the body looks like but how the flow of blood is distributed'. Quite so.

These methodological problems show that Dwyer's work cannot be used as a basis for wide-ranging generalisations. His conclusions (which are, to do him justice, suitably modest) should not be extrapolated to cover all kinds of diagrams and tasks. The narrow range of stimuli and tasks sets a boundary to the field of validity.

Babbage C 1961
Charles Babbage and his calculating machines: selected writings by Charles Babbage and others
New York, Dover

Beakley G 1974
Graphics for design and visualization
Cassell

Bronfenbrenner U 1944
The graphic presentation of sociometric data
Sociometry 7:283-289

David RE 1972
Proposal for a diagrammatic language for design
Visible Language 6:123-137

Dunsheath CBE 1962
A history of electrical engineering
Faber

Dwyer FM 1967
Adapting visual illustrations for effective learning
Harvard Ed Rev 37:250-263

Dwyer FM 1968
Effect of varying amount of realistic detail in visual illustrations designed to complement programmed instruction
Perceptual and Motor Skills 27:351-354

Dwyer FM 1968
Effect of visual stimuli on varied learning objectives
Perceptual and Motor Skills 27:1067-1070

Dwyer FM 1968
The effectiveness of selected visual illustrations in teaching science concepts to college freshmen
J Ed Res 61:343-347

Dwyer FM 1968
The effectiveness of visual illustrations used to complement programmed instruction
J Psychol 70:157-162

Dwyer FM 1969
An experiment in visual communication
J Research in Science Teaching 6:185-195

Dwyer FM 1969
Student perception of the instructional value of visual illustration
Medical and Biological Illustration 19:42-45

Dwyer FM 1970
Effect of questions on visual learning
Perceptual and Motor Skills 30:51-54

Dwyer FM 1970
Exploratory studies in the effectiveness of visual illustrations
AV Comm Rev 18:235-249

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Medical and Biological Illustration 21:10-13

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Effect of questions on visualised instruction
J Psychol 78:181-183

Dwyer FM 1971
Questions as advanced organisers in visualised instruction
J Psychol 78:261-264

Dwyer FM 1972
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Prog Learning & Ed Tech 8:73-80

Dwyer FM 1972
The effects of overt response in improving visually programmed science instruction
J Research in Science Teaching 9:47-55

Dwyer FM 1972
A guide for improving visualised instruction
Pennsylvania State College Learning Services

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Science 174:no14013:993-1000

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in The visual communication of scientific and technical information
Harwell, Society of Industrial Artists and Designers conference

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The artist in the service of science
Zurich, Graphis

Herdeg W ed 1974
Diagrams: the graphic visualization of abstract data
Zurich, Graphis

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Symmetrical gaits of horses
Science 150:701-708

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New York, Wiley

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Chance and choice by cardpack and chessboard: an introduction to probability in practice by visual aids
Parrish

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Mathematics in the making
Macdonald

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Pictorial statistics and diagrams
Penrose Annual 38:67-69

How things work: the universal encyclopaedia of machines 2v
Paladin 1972 1974

John VB 1974
Understanding phase diagrams
Macmillan

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An introduction to engineering and engineering design
New York, Wiley

Levens AS 1954
Graphics in engineering and science
New York, Wiley

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Diagrams: a visual survey of graphs, maps, charts and diagrams for the graphic designer
Studio Vista

Lowe R and Mansell JW 1967
Basic electrical circuit theory
Pitman

McNally D 1975
Positional astronomy
Muller

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The ability of children to read a process diagram
J Ed Psychol 38:290-298

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The ability of children to read conventionalised diagrammatic symbols
J Ed Psychol 39:27-34

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Children's ability to read diagrammatic materials
Elementary School J 49:98-102

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New York, McGraw-Hill

Marples DL 1960
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Engineering Designer (Dec) 1-16

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The origins of feedback control
Cambridge, Mass. MIT Pr

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The graphic language of organisation
in Meredith P ed
Learning, remembering and knowing
English Universities Pr

Needham J 1954-
Science and civilisation in China
Cambridge U Pr

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Die Botanische Buchillustration
Stuttgart

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Dynamical analogies
Chapman and Hall

Panell JPM 1964
An illustrated history of civil engineering
Thames and Hudson

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The cyclopaedia or Universal dictionary of arts, sciences and literature 5 v
David & Charles 1972

Ridgway JL 1938
Scientific illustration
Stanford U Pr

Rowland KT 1974
Eighteenth century inventions
David & Charles

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The study of the history of mathematics, and
The study of the history of science
New York, Dover

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Fundamentals of flowcharting
New York, Wiley

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Mechanical engineering design
New York, McGraw-Hill

Singer C ed 1954
A history of technology 5 v
Oxford U Pr

Smith IM and Nosie KT 1972
Basic electrical engineering science
Longman

Stankowski A 1967
Visual presentation of invisible processes
Tiranti

Tennett RM 1971
Science data book
Oliver and Boyd

Toulmin SE 1953
Philosophy of science
Cambridge U Pr

Usher AP 1954
A history of mechanical inventions
Harvard U Pr

Vries L de 1958
The book of experiments
Murray

Weisberg JS 1970
The use of visual advance organisers for learning earth science concepts
J Research in Science Teaching 7:161-165

Wilson WE 1965
Concepts of engineering system design
New York, McGraw-Hill

Zweiffel FWA 1961
A handbook of biological illustrations
Chicago U Pr

5.2 Operational diagrams

These are technical diagrams associated with clear-cut operational tasks such as setting-up, operating, maintaining and repairing complex equipment. The systematic investigation of such diagrams dates back to the early work on task analysis: after deciding what information is relevant to particular tasks comes the question of *format*. Often all the information is in diagrammatic form with words used for labels and instructions; the diagrams carry the burden of the job-relevant instruction. Typical task situations would be

– assembling a machine-gun
– repairing a tank in the field
– trouble-shooting electronic equipment at sea
– trouble-shooting and repairing television sets.

All complex equipment needs support documentation; but much of this documentation is prepared unsystematically without task analysis or field trials. The true operational diagram is the product of a process of analysis and testing which 'guarantees' its effectiveness. The most characteristic result of this systematic process is the reduction of theoretical and 'nice-to-know'

information, the simplification of the prose and increased sophistication of the diagrams, which are of various kinds:

- photographs or drawings of the equipment
- functional block diagrams of the system
- detailed circuit diagrams
- maintenance dependency charts
- algorithms

The references listed below are probably not complete; the older technical reports are scarce even in the USA and almost unobtainable elsewhere. Those who can get hold of Shriver's papers on the FORECAST system of task analysis will be well rewarded; the conceptual basis and empirical evidence are laid out carefully. This work completed the idea of a 'technology of training' which had been developing since the Second World War.

Outside the USA there has been little original work on task analysis, and hence no significant work on operational diagrams. The Royal Navy's FIMS system is a straightforward copy which has in turn been copied (and modified) by some large UK organisations (such as Rank Xerox and the BBC). Since it is by no means easy to copy the quality of analysis and testing that made the original task analysis so impressive the benefit of the novel format for 'job-support' literature may become rather uncertain. It is easy to mistake the form for the substance.

Amos SW 1973
Presenting maintenance information: techniques developed by BBC use functional diagrams and minimum of text
Wireless World 79:510-514

Baker RA 1958
The determination of job requirements for tank crew members
HumRRO Technical report 47

Elliott TK 1965
Effect of format and detail on job-performance aids in performing simulated troubleshooting tasks
Applied Science Associates Inc

Fink CD 1967
Technical manuals for maintenance support: a maintenance rationale, some research findings and some projections
HumRRO Professional paper 37-67

Folley JD 1961
Research problems in the design of performance aids
Am Institutes for Research ASD Technical report 61-548

FIMS Development Group HMS Collingwood Fareham Hants
New guide to Functionally Identified Maintenance Systems 1972

Hoehn AJ 1960
The development of training programs for first enlistment personnel in electronics maintenance MOS's - III: How to design handbook materials
HumRRO Research memorandum

Hoehn AJ and Lumsdaine AA 1958
Design and use of job aids for communicating technical information
Lackland Air Force Base Texas, Air Force Personnel and Training Research Center (Technical report AFPTRC-TR-58-7, ASTIA Document no AD152 109)

Jakes B 1973
An introduction to FIMS and DDS (Development Documentation System)
Communicator 15:2-7

Konz S, Dickey GL, McCutchan CM and Daniels RW 1966
Manufacturing assembly instructions I
J Industrial Engineering 17:243-253

Konz S and Dickey G 1967
Manufacturing assembly instructions II: Combinations and forms of media
J Industrial Engineering 18:63-69

Konz S, Dickey GL, McCutchan C and Koe B 1967
Manufacturing assembly instructions III: Abstraction, complexity and information theory
J Industrial Engineering 18:658-667

Konz S and Dickey GL 1969
Manufacturing assembly instructions: a summary
Ergonomics 12:369-382

Langham-Brown JB 1971
Training for fault diagrams (FIMS)
BACIE J 25:9-14

Lippert HB 1965
DATOM: a new support publications concept
STWP Rev 12:12-14

Rank Xerox 1974
Service manual specifications, standards and guidelines

Reese DW 1959
Guide to design of Air Force check-list publications
Aerospace Medical Laboratory

Shimberg HL 1971
A new package for troublesome loop diagrams
Tech Communicator 18:6-9

Shimberg HL 1973
Effective presentation of maintenance information using decision logic tables
Tech Communicator 20:10-13

Shriver EL 1960
Determining training requirements for electronic system maintenance: development of a new method of skill and knowledge analysis
HumRRO Technical report 63

Shriver EL and Fink CD 1964
FORECAST systems analyses and training methods for electronic maintenance training
HumRRO Research report 13

Ware JR, Miller EE and Constantinides JL 1968
Pictorial methods of instruction for the M73 machine gun and the caliber 145 automatic pistol: consulting report
George Washington University HumRRO

Ware JR, Miller EE and Constantinides JL 1969
Project PIMO (Presentation of Information for Maintenance and Operation) Final report - PIMO Report Summary vol I TR-69-155
Serendipity Inc

5.3 Engineering drawing

The skill of engineering drawing has an extensive history (see Booker), though its emergence as a specialised technical discipline coincides with the industrial revolution. The discipline has its own experimental literature: Spencer and his colleagues have investigated the choice of projection and the organisation of information on engineering drawings. As usual, the design of experiments is most satisfactory when there are realistic tasks for the learner to perform – Spencer comments 'The study of dimension presentation proved difficult because it was less easy to develop a single realistic task with objective scoring.'

Architectural drawing has some conceptual similarity, and is also placed in this section.

Booker PJ 1963
A history of engineering drawing
Chatto & Windus

Brizio AM 1974
The Madrid notebooks: new aspects of Leonardo's genius emerge from his rediscovered manuscripts
Unesco Courier (Oct) 8-15

Broadbent G 1973
Design in architecture: architecture and the human science
New York, Wiley

Burdick JG 1959
A study of cross-section drawings used as technical illustrations in high school science textbooks
Diss Abs 20(7)2707-2708

Burstall AF 1963
A history of mechanical engineering
Faber

Cheney RL and Spencer J 1974
Dimensional information on engineering drawing
Ergonomics 17:343-363

Davies TN 1973
Visual perception of engineering drawings
Engineering Designer 4:22-31

Davies TN 1976
The span of visual perception in engineering drawing
Communicator of Scientific & Technical Information 27:2-11

Diderot D 1751
Pictorial encyclopaedia of trades and industry
New York, Dover 1959

Dubery F and Willats J 1972
Drawing systems
Studio Vista

Ergonomic Research Society and Society of Industrial Artists and Designers 1973
The visual presentation of Technical data
University of Reading Typography Unit

French MJ 1971
Engineering design: the conceptual stage
Heinemann

Gibby JC 1970
Technical illustration: procedure and practice 4th ed
Chicago, American Technical Society

Giesecke FE, Mitchell A, Spencer HC and Hill IL 1974
Technical drawing 6th ed
New York, Macmillan

Gille B 1966
The Renaissance engineers
Lund Humphries

Goodey J and Matthew K 1971
Technical information for architects
Applied Ergonomics 2:198-206

Hart IB 1963
The mechanical investigations of Leonardo da Vinci
U California Pr

Hewitt TH 1974
Advanced geometrical and engineering drawing
U London Pr

Hoelscher RP, Springer CH and Dobrovolny JS 1968
Graphics for engineers: visualization, communication and design
New York, Wiley

Krick EV 1965
An introduction to engineering and engineering design
New York, Wiley

Leonardo da Vinci
Selections from the notebooks ed IA Richter
Oxford U Pr 1952

Levens AS 1968
Graphics: analysis and conceptual design 2nd ed
New York, Wiley

Magnan GA 1971
Industrial illustrating and layout
in Jordan S ed
Handbook of technical writing practices vol 2 chap 15
New York, Wiley

Marples DL 1960
The decisions of engineering design
Engineering Designer (Dec) 1-16

Martin CL 1970
Architectural graphics 2nd ed
Macmillan

Morgan SW 1950
Architectural drawing
New York, McGraw-Hill

Ramsey CG and Sleeper HR 1970
Architectural graphic standards 6th ed
New York, Wiley

Reti L 1971
Leonardo on bearings and gears
Scientific American 224:100-110

Reti L 1974
The unknown Leonardo
New York, McGraw-Hill

Ruzinov LD 1968
Design of mechanisms by geometrical transformations
Iliffe

Simmons CH and Maguire DE 1974
A manual of engineering drawing practice
English Universities Pr

Sleeper HR 1940
Architectural specifications
New York, Wiley

Spencer J 1963
A preliminary enquiry into engineering drawing comprehension
Occup Psychol 37:181-195

Spencer J 1965
Experiments on engineering drawing comprehension
Ergonomics 8:93-110

Spencer J 1973
Presentation of information on engineering drawings
in ERS/SIAD
Presentation of technical data
University of Reading Typography Unit

Spencer J and Cheney RL 1971
Comprehension of numerical information on engineering drawings
Engineering Designer (August)

Spencer J and Milnes-Walker ND 1971
The ergonomics study of engineering drawings
Appl Ergonomics 2:162-170

Spencer J and Cheney RL 1972
Tolerances on engineering drawings
Int J Professional Research 10:333-349

Thomas TA 1968
Technical illustration
New York, McGraw-Hill

Turner B 1967
Effective communication: design into practice
Engineering Designer (Sept) 8-20

Wallis NB 1963
Artist or engineer?
Engineering Designer (Sept)

6.1 Ordinary language algorithms

'An algorithm is an orderly sequence of instructions for solving a problem -- a visual instrument of telling' *Lewis*

The term 'algorithm' is used in two different (but related) senses. In computer science it means a procedure which produces correct results (as opposed to an heuristic); but instructional technologists usually reserve the term for ordinary language algorithms. This has led to a good deal of confusion, which we try to avoid by segregating the computer science usage in section 6.2 and ordinary language algorithms in this section.

Ordinary language algorithms display the structure of rules, regulations, instructions and procedures in non-continuous prose -- usually as flow charts, sometimes in list format. When in continuous prose knowledge of this kind consists of a connected set of statements and instructions linked by the crucial words: *if, then, unless*. Lewis therefore defined ordinary language (OL) algorithms as 'a canonical form for representing the structure of coherent "if ... then ... unless" conditionals'. This definition is linguistic (and not mathematical) and fairly precise: it tells you what kind of prose can, in principle, be reordered in algorithmic format.

The theory and practice of OL algorithms was hammered out more or less independently and simultaneously by Wason at University College London and Lewis at Cambridge Consultants Ltd (together with their co-workers). The papers by Lewis are of the highest standard; his (1967b) review (CAS Paper No 2) is generally regarded as the best introduction to the subject, and has been reprinted several times. On the other hand the self-instructional manuals (Lewis and Woolfenden; and Wheatley and Unwin) are rather too elementary, though they do contain some practical pointers.

An algorithm asks the reader one question at a time, and that question is posed directly using language that can be understood by the whole target population. This means that the user only needs to deal with the one pathway relevant to his needs. To achieve this the original text must be logically analysed and visually displayed. The logical analysis often turns up loopholes or ambiguities in the original which are quite invisible to any ordinary inspection. The visual display dissects the regulation into its component parts, making visible the joints or logical connections. The decision about what to include or leave out is often difficult. These algorithms are not necessarily complete; they must just be adequate for some particular purpose.

There have been various empirical tests of OL algorithms against continuous prose rules and regulations; all these tests are decisively in favour of algorithms. This is one of the occasions when instructional technologists have managed to provide us with a really solid prescription.

Cambridge Consultants (Training) Ltd 1967
Evaluation report on a training programme for instrument artificers

Cambridge Consultants (Training) Ltd 1969
Employer's guide to claiming grants
Wool, Jute and Flax Industry Training Board

Davies IK 1970
Algorithms
Psychology today 3:53-69

Davies IK 1970
Algorithms: a strategy for overcoming communication problems
RAF Education Bul 7:39-50

Davies IK 1971
Algorithms
in Davies IK ed
The management of education pp 137-146
New York, McGraw-Hill

Gane CP, Horabin IS and Lewis BN 1966
The simplification and avoidance of instruction
Industrial Training International (July) 160-165

Gane CP, Horabin IS and Lewis BN 1967
Algorithms for decision making
in Aspects of Educational Technology pp 481-502
Methuen

Gane CP and Woolfenden PJ 1968
Algorithms and the analysis of skilled behavior
Industrial Training International (July) 312-317

Horabin IS 1972
Algorithms
Improving human performance 1

Jones S 1964
Why can't leaflets be logical?
New Society 102

Jones S and Wason PC 1965
The logical tree project
University College, London Dept of Psychology

Kammann R 1975
The comprehensibility of printed instructions and the flowchart alternatives
Human Factors 17:183-191

Lewis BN 1970
Decision logic tables for algorithms and logical trees
HMSO CAS Occasional paper no12

Lewis BN 1971
Getting the message across
NCSS Working Seminar on The Methods of Communicators applied to social workers
23 Nov 1971

Lewis BN 1971
On the nature of human problem solving
Discussion notes prepared for CRAC course
U of Reading 4-10 July 1971

Lewis BN and Cook JA 1968
Some comments and recommendations concerning inter-coder reliability
Psychol Reports 22:1213-1225

Lewis BN and Cook JA 1969
Toward a theory of telling
Int J Man-Machine Studies 1:129-176

Lewis BN and Edwards K 1966
Short cuts to problem solving
New Society (20 Oct) 607-609

Lewis BN, Horabin IS and Gane CP 1967
Case studies in the use of algorithms
Pergamon

Lewis BN, Horabin IS and Gane CP 1967
Flow charts, logical trees and algorithms for rules and regulations
HMSO CAS Occasional paper no 2

Lewis BN and Woolfenden PJ 1969
Algorithms and logical trees: a self-instructional course
Cambridge, Algorithms Pr

Ryan WS, Willis VAC and Brook PW 1970
The increasing use of logical trees in the Civil Service
HMSO CAS Occasional paper no 13

Shimberg HL 1973
Effective presentation of maintenance information using logic tables
Technical Communications 20:10-13

Wason PC 1968
The drafting of rules
New Law J 118:548-549

Wason PC 1972
The understanding of regulations
in Wason PC and Johnson-Laird PN
Psychology of reasoning: structure and content
Batsford

Wheatley DM and Unwin AW 1972
The algorithm writer's guide
Longman

Wright P 1969
Transformations and the understanding of sentences sentences
Language and Speech 12:156-166

Wright P 1971
Writing to be understood: why use sentences?
Appl Ergonomics 2:207-209

Wright P and Reid F 1973
Written information: some alternatives to prose for expressing the outcomes of complex contingences
J Appl Psychol 57:160-166

Wright P 1975
Presenting people with choices: the effect of format on the comprehension of examination rubrics
Prog Learning & Ed Tech 12:109-114

6.2 Numerical and symbolic algorithms

It will not do to conflate OL algorithms (which are linguistic entities) with mathematical and computing algorithms; but unhappily this often does happen. Still less should any kind of flow-chart describing any sort of system be labelled 'algorithm'. A certain amount of conceptual confusion is inevitable with novel problems, but nothing is gained by conflating unlike entities.

The reviews by Gerlach and Merrill are important sources, though I cannot help feeling they have also tended to use the term algorithm as a portmanteau word. Bung, Landa and Scandura are included here because their interest in well specified rules and procedures seems connected to the growth of computing concepts; their work is quite individual and contains many interesting ideas though (to be honest) the style of these works is not everyone's cup of tea.

Arden BW and Astill KN 1970
Numerical algorithms: origins and applications
Reading, Mass. Addison-Wesley

Bellman R, Cooke KL and Lockett JA 1970
Algorithms, graphs and computers
Academic Pr

Bung K 1969
Prior knowledge analysis for programmed instruction
RECALL 1:98-117

Bung K 1972
Teaching algorithms, learning algorithms
Paper presented at the Annual Conference Assoc for Programmed Learning & Educational Technology

Chilcote E 1970
Flowchart stories: a systems approach to creative writing
Grade Teacher 88:66-69

Elliott RE 1972
Problem solving and flowcharting
Reston, Virginia, Reston Pub Co

Farina MV 1970
Flowcharting
New Jersey, Prentice-Hall

Garfield E 1973
Historiographs, librarianship and the history of science
in Rawski CH ed
Toward a theory of librarianship pp 380-402
New York, Scarecrow Pr

Gerlach VS, Reiser RA and Brecke FH 1975
Algorithms in learning, teaching and instructional design
Arizona State U Ed Tech
USAF Office of Scientific Research Grant no 75-2900
Technical report 51201

Landa LN 1974
Algorithmization in learning and instruction
New Jersey, Ed Tech Pubs

Lansky M 1969
Learning algorithms as a teaching aid
RECALL 1:81-89

Maltsev AI 1970
Algorithms and recursive functions
Groningen, Netherlands, Wolters-Noordhoff

Markov AA 1961
Theory of algorithms
Washington, National Science Foundation

Merrill PF 1974
Algorithmic organization in teaching and learning: the literature and research in the USA
Florida State U Center for Educational Design

Mueller FJ 1970
Games and algorithms: a new view in elementary school mathematics for teachers
University of Maryland Mathematics project
Arithmetic Teacher 17:342-346

Overholser JS 1966
Flowcharts for the elementary grades
Arithmetic Teacher 13:59-63

Scandura JM 1973
Structural learning: the theory and empirical research
New York, Gordon Breach Science Pubs

Trakhenbrot BA 1963
Algorithms and automatic computing machines
Boston, Heath

Weaver DH 1969
Flowcharting as a teaching/learning tool
Business Education World 49:18-20

Yee AH, Shores J and Skuldt K 1970
Systematic flowcharting of educational objectives and processes
AV Comm Rev 18:72-83

7.1 Typography: general

'Die Typographie ist ein Instrument der Mitteilung' *Moholy-Nagy*
'The true economics of printing must be measured by how much is read and understood and not by how much is produced'. *Spencer*

Printing with movable type is one of the great mechanical inventions. Five hundred years old in the West (and perhaps a thousand years old in China), this industrial art makes it possible to distribute information rapidly and relatively cheaply to all who can read. The growth of science and the industrial revolution would have been stunted without print; and (for good or ill) the modern bureaucratic state could not function at all without it.

Originally typography – the art of arranging print on the page – was constrained by the mechanical imperatives of the printing method. As techniques progressed printing became faster and eventually more flexible. Automatic presses replaced hand presses; mechanical composing machines replaced hand composing; lithography was invented ... all this by the end of the nineteenth century. Now we have film composition, computer printing and xerography: these modern processes are collectively called 'cold composition', which term signals the disappearance of those little pieces of lead ('hot metal') which pinned typography down with mechanical limitations. Now any marks on paper can be reproduced, and this freedom marks a permanent change in the typographer's role. Once he was a skilled interpreter of mechanical constraints – now he can become a communicator. That is why the first sentence from Moholy-Nagy's manifesto for the New Typography heads this section.

This section contains some of the great classics of typography: Dowding, Gill, Morison, Tschichold and Williamson are essential reading. How do these master performers judge what is 'good typography'? Do they, as some researchers suggested, rely mainly upon 'aesthetic' criteria? No. They rely upon rational argument and the evidence of their experienced eyes (remember Klee's 'thinking eye'?). Let's look at Dowding's discussion of word spacing as one example:
'From the time of the invention of printing from movable types in Europe, that is, circa 1440, up to the present day, one of the hall-marks of good printing, and of the good printer, has been the care and attention paid to the setting of text matter ... when words are set for continuous reading they should always be *closely* spaced ... Why has this tradition of close spacing survived? ... the eyes of the adult reader take in a group of words at each glance ... the normal, easy, left-to-right movement of the eye is slowed down by over-widely separated words.' (Dowding 1966).

How well 'pre-scientific' crafts solve difficult technical problems without the benefit of formal empirical tests! This is something of a mystery, but a mystery which can be dispelled by learning to use our eyes! The eye is a stupendous device for making comparisons; we must entertain the possibility that an expert craftsman can by the intelligent use of his eyes reach better solutions to particular problems than the researcher in his laboratory.

Despite the excellent standards set by the master typographers it is quite easy to collect examples of bad practice – violations of well-founded principles. Recently we have seen these from famous publishing houses:
– ragged *left* edge. This disrupts the eye-movement pattern
– illegible second colour. Yellow/orange can hardly be seen under household lights
– lack of contrast between print and paper
– large slabs of text set in upper case and italic
– type-size 6-point in book setting
– uneven and excessive word spacing.

In paperback editions three or four substandard or marginal conditions may occur together. And here is *is* worth quoting Tinker's work on the cumulative effect of non-optimal arrangements.

These mistakes are infuriating, but not theoretically interesting. Commonsense and elementary training would dispose of all such cases.

The real interest lies in problems which have not yet yielded either to traditional craft knowledge or to modern laboratory research. Educational materials are one such case. These educational texts are extremely complex typographically: they contain title, contents, section numbering system, glossary, index, running heads, section headings, page numbers, footnotes, references, tables, photographs, diagrams, captions, questions and answers, instructions, mathematical formulae or other special notations, type face, type size, word spacing, interlinear spacing, line length, use of space, columns, boxes and rules, cover design, binding, page size. Also the designer must consider the production system, the conditions of usage and the needs of marketing. Over thirty issues must be resolved by the typographer or book designer. All items on the list interact with some other items, which means that one optimal solution is quite unlikely – satisficing is the name of the game. Also, these interactions make nonsense of the one-variable tests that make up so much of the classical literature. There are two surveys which look especially at the typography of educational materials (Hartley *et al;* Macdonald-Ross and Waller). The survey of Open University texts showed that their setting is far more complex than normal text setting. Most of the research has been done on simplified stimulus material, thus leaving designers no guide (at any rate, no formal scientific guide) for the more complex decisions they must take.

Arnold EC 1972
Ink on paper 2: a handbook of the graphic arts
New York, Harper

Bain EK 1970
Display typography
Focal Pr

Biggs JR 1961
An approach to type
Pitman

Biggs JR 1969
Basic typography
Faber

Burke PW 1973
The book in a changing climate
Icographic 5:10-11

Chappell W 1972
A short history of the printed word
Deutsch

Craig J 1974
Designing with type
Lund Humphries

Dair C 1967
Design with type
U Toronto Pr

Dowding G 1966
Finer points in the spacing and arrangment of type
Wace

Garland K 1968
Graphics handbook
Studio Handbook

Gerstner K 1974
Compendium for literates: the systematics of writing
Cambridge, Mass. MIT Pr

Gill E 1931
An essay on typography
Sheed & Ward

Hartley J and Burnhill P eds 1975
Typographical research
Prog Learning & Ed Tech v 12 pt 2 special issue

Hartley J and Burnhill P (in press)
Textbook design: a practical guide
Paris, Unesco, Division of Materials & Techniques

Hartley J, Fraser S and Burnhill P 1974
A selcted bibliography of typographical research relevant to the production of instructional materials
AV Comm Rev 22:181-190

Hurlburt A 1972
Publication design: a guide to page layout, typography, format and style
New York, Van Nostrand

Hutchins M 1969
Typographics: a designer's handbook of printing techniques
Studio Vista

Kapr A 1973
Some tasks for future book design
Icographic 5:8-9

Kneebone P and Facetti G 1973
The role of the book designer
Icographic 5:4

Macdonald-Ross M and Waller R 1975
Open University texts: criticism and alternatives
Open U, Institute of Ed Tech

McLean R 1975
Jan Tschichold: typographer
Lund Humphries

Moran J ed 1974
Printing in the 20th century: a Penrose anthology
Northwood

Morison S 1967
First principles of typography
Cambridge U Pr

Ovink GW 1973
The changing responsibilities of the typographic designer
Icographic 5:16-18

Ruder E 1967
Typography: a manual of design
Hastings

Ruegg R and Frolich G 1972
Basic typography: a handbook of technique and design
New York, Hastings

Simon O 1963
Introduction to typography
Faber

Spencer H 1952
Design in business printing
Sylvan

Spencer H 1968
The visible word
Lund Humphries

Swann C 1969
Techniques of typography
Lund Humphries

Tschichold J 1967
Asymmetric typography
New York, Van Nostrand

Turnbull AT and Baird RN 1968
The graphics of communication: typography layout and design 2nd ed
New York, Holt, Rinehart and Winston

Twyman ML 1970
Printing from 1770-1970
Eyre and Spottiswoode

Warford HS 1971
Design for print production
Focal Pr

White JV 1974
Editing by design: word-and-picture communication for editors and designers
New York, Bowker

Williamson H 1966
Methods of book design 2nd ed
Oxford U Pr

Wright E 1973
The essential book
Icographic 5:12-15

Zapf H 1970
Manuale typographicum
Cambridge, Mass. MIT Pr

7.2 Legibility

If we take the results of legibility research at face value, as Rehe does, then we are bound to conclude that a great deal of useful work has been done, and what we need is more of the same. If, on the other hand, we take a critical look at the details of experimental design then maybe (as Macdonald-Ross and Waller suggest) much of the effort put into empirical testing has simply been wasted.

In the first place there are results which we can accept as valid, for example, text set in upper case is less legible than the equivalent in lower case. This is true, but it's not news. It has been realised for a long time that text set in upper case lacks 'word shape' clues. In a similar way, Tinker showed that too litle or too much 'leading' (nowadays, interlinear spacing) would affect legibility adversely. Fair enough. But this kind of knowledge has been the stock-in-trade of the master-printer for centuries! So is empirical research just a kind of 'aid to rhetoric' whereby educated people (who don't understand or won't accept the experiential basis of craft knowledge) will take heed of advice if it has a 'scientific' seal of approval?

Of course, scientific research cannot be justified just because its results carry authority. Rather, science carries authority when it leads to surprising and novel truths, deep and interesting principles and theories. When these foundations allow practical tasks to be better accomplished, we all rightly applaud. This is not the case with research into typography. As a matter of fact both book and newspaper typography has improved during the last century (see examples in Vernon 1946 and Hutt 1967, 1973) – but not due to formal empirical research. However, for those who value the classical laboratory experiment Tinker's famous textbook remains an indispensable source.

Perhaps the greatest tribute to Tinker is that all text researchers must have a copy – even those of us who don't find the methodology convincing! The harshest critics of Tinker are practising designers and typographers who point out (correctly) that their daily task is to satisfy complex sets of conditions which interact strongly. Such problems are deliberately evaded by the classical method, so that while researchers ask 'why do designers ignore research findings?', designers say 'researchers have nothing of real interest to teach us.' This mutual incomprehension is a chief reason why *both* professions have made less progress than one might have expected. We see here two epistemologies (knowledge from controlled experiments vs. knowledge from personal trial and experience) and two tasks (universal knowledge vs. particular solutions). The question is, shall these differences continue to cause misunderstanding, or can they be mutually supportive?

Bartz BS 1970
An analysis of the typographic legibility literature: assessment of its applicability to cartography
Cartographic J 7:10-16

Bryden MP 1968
Symmetry of letters as a factor in tachistoscopic recognition
Am J Psychol 81:513-524

Buckingham BR 1931
New data on the typography of textbooks
Yearbook National Society for the Study of Education
30:93-125

Burnhill P and Hartley J 1975
Psychology and textbook design: a research criticism
Aspects of Ed Tech
Pitman 8:65-78

Burt C 1959
A psychological study of typography
Cambridge U Pr rep 1974

Burt C 1960
The typography of children's books, a record of research in the United Kingdom
Yearbook of Education pp 242-256

Burt C, Cooper WF and Martin JL 1955
A psychological study of typography
Br J Statistical Psychol 8:29-57

Burtt HE 1949
Typography and readability
Elementary English 26:212-221

Carr R 1969
The legibility of signs
Print 23:28-31

Carte JA 1973
Filtering typographic noise from technical literature
Technical Communicator 20:13

Cheetham D, Poulton EC and Grimbly B 1965
Graphics: the case for research
Design 196:48-51

Cornog DY and Rose FC 1967
Legibility of alphanumeric characters and other symbols
Washington US Dept of Commerce
National Bureau of Standards

Demilia LA 1968
Visual fatigue and reading
J Education 151:4-34

Erdmann RL and Neal AS 1968
Word legibility as a function of letter legibility with word size, word familiarity and resolution as parameters
J Appl Psychol 52:403-409

Fishenden RB 1946
Types, paper and printing in relation to eye strain
Br J Ophthalmology 30:20-26

Fisher DF, Monty RA and Glucksbert 1969
Visual confusion matrices: fact or artifact?
J Psychol 71:111-125

Foster JJ 1965
Psychological research into legibility
J Typog Res 2:279-282

Foster JJ ed 1971
Legibility Research Abstracts 1970
Lund Humphries

Foster JJ 1972
Legibility Research Abstracts 1971
Lund Humphries

Hartley J and Burnhill P 1976
Explorations in space
Bul Br Psychol Soc 29:97-107

Hartley J, Burnhill P and Fraser S 1973
Typography, communication and learning
in ERS/SIAD
The visual presentation of technical data
University of Reading Typography Unit

Hartley J, Burnhill P and Fraser S 1974
Typographical problems of journal design
Appl Ergonomics 5:15-20

Kolers PA 1969
Clues to a letter's recognition: implications for the design of characters
J Typog Res 3:145-168

Luckiesh M and Moss FK 1940
Criteria of readability
J Exp Psychol 27:256-279

Luckiesh M and Moss FK 1942
Reading as a visual task
New York, Van Nostrand

Macdonald-Ross M and Waller R 1975
Criticism, alternatives and tests: a conceptual framework for improving typography
Prog Learning & Ed Tech 12:75-83

North J and Jenkins EB 1951
Reading speed and comprehension as a function of typography
J Appl Psychol 35:225-228

Ovink GW 1938
Legibility atmosphere-value and forms of printing types
Leiden, AW Sijthoff's Uitgerersmaatschappij

Paterson DG and Tinker MA 1940
How to make type readaule
New York, Harper

Poulton EC 1958
On reading and visual fatigue
Am J Psychol 71:609-611

Poulton EC 1965
Letter differentiation and rate of comprehension in reading
J Appl Psychol 49:358-362

Poulton EC 1968
The measurement of legibility
Printing Technology 12:2-6

Poulton EC 1969
How efficient is print?
New Society 13:869-871

Poulton EC, Warren TT and Bond J 1970
Ergonomics in journal design
Appl Ergonomics 1:207-209

Prince JH 1967
Printing for the visually handicapped
J Typog Res 1:31-47

Pyke RL 1926
Report on the legibility of print
HMSO Medical Research Council special report 110

Rehe RF 1970
Psychological studies and their impact on modern typography
Inland Printer/American Lithographer 66:53

Rehe RH 1974
Typography: how to make it most legible
Indianapolis, Design Research Pubs

Salcedo RN, Read H, Evans JF and Kong AC 1972
A broader look at legibility
Journalism Q 49:285-289

Shaw A 1973
Some methodological problems in legibility research
in ERS/SIAD
The visual presentation of technical data
University of Reading Typography Unit

Shillman R, Cox C, Kuklinski T, Ventura J, Eden M and Blesser B 1974
A bibliography in character recognition: techniques for describing characters
Visible Language 8:151-166

Stringer P 1974
A use of repertory grid measures for evaluating map formats
Br J Psychol 65:23-44

Tinker MA 1955
Prolonged reading tasks in visual research
J Appl Psychol 39:444-446

Tinker MA 1963
Legibility of print
Iowa State U Pr

Tinker MA 1966
Experimental studies in the legibility of print: an annotated bibliography
Reading Res Q 1:68-118

Tinker MA 1968
Suitable typography for beginners in reading
Education 88:317-320

Vernon MD 1946
On the legibility of print
International Printing 1:33-41

Watts L and Nisbet J 1974
Legibility of children's books
National Federation of Educational Research

Zachrisson B 1965
Legibility of printed text
Stockholm, Almqvist & Wiksell

7.3 Prose setting

This section contains some experiments on the basic elements of text setting – choice of face and size, line-length, interline space and justification of right-hand margin. The paper by Tinker on curved text is part of his work on the hygienic reading situation. Many people read in substandard conditions – poor light, glare, text not at right angles to the line of sight; the reader may be tired, disinterested; the room may be noisy; interruptions and distractions may occur. All this will, of course, make reading less efficient. We may well suspect that 'no difference' results would be less frequent in substandard reading conditions.

Becker D, Heinrich J, von Sichowshy R and Wendt D 1970
Reader preferences for typeface and leading
J Typog Res 4:61-66

Burnhill P 1970
Typographic education: headings in text
J Typog Res 4:353-365

Carte JA 1974
Is justification justifiable?
Tech Communicator 21:7-10

Carver RP 1970
Effect of a 'chunked' typography on reading rate and comprehension
J Appl Psychol 54:288-296

Cheetham D and Grimbly B 1964
Design analysis: type face
Design 186:61-71

Coleman EB and Hahn SC 1966
Failure to improve readability with a vertical typography
J Appl Psychol 50:435-436

Coleman EB and Kim I 1961
Comparison of several styles of typography in English
J Appl Psychol 45:262-267

Coles P and Foster J 1975
Typography cueing as an aid to learning from typewritten text
Prog Learning & Ed Tech 12:102-108

Davenport JS and Smith SA 1965
The effect of hyphenation, justification and type size in newspaper readability
Journalism Q 42:387

Evers CH 1968
Adjustment to unjustified composition on the Rotterdamsch Nieusblad
J Typog Res 2:59-74

Fabrizio R, Kaplan I and Teal G 1967
Readability as a function of the straightness of right-hand margins
J Typog Res 1:90-95

Foster JJ 1970
A study of the legibility of one- and two-column layouts for BPS publications
Bull Br Psychol Soc 23:113-114

Gregory M and Poulton EC 1970
Even versus uneven right-hand margins and the rate of comprehension in reading
Ergonomics 13:427-434

Hartley J and Burnhill P 1971
Experiments with unjustified text
Visible Language 5:265-278

Hartley J and Burnhill P 1976
Explorations in space: a critique of the typography of BPS publications
Bul Br Psychol Soc 29:97-107

Hartley J and Mills RI 1973
Unjustified experiments in typographical research and instructional design
Br J Ed Tech 4:120-131

Hartley J and Young M 1975
The effects of interline space on judgements of typesize
Prog Learning & Ed Tech 12:115-119

Klare GR, Nichols WH and Shuford EH 1957
The relationship of typographic arrangement to the learning of technical training material
J Appl Psychol 41:41-45

Marks MB 1966
Improve reading through better format
J Ed Res 60:147-151

Nahinsky ID 1956
The influence of certain typographical arrangements upon the span of visual comprehension
J Appl Psychol 40:37-39

Paterson DG and Tinker MA 1932
Studies of typographical factors influencing speed of reading: 8 Space between lines or leading
J Appl Psychol 16:388-397

Paterson DG and Tinker MA 1932
Studies of typographical factors influencing speed of reading: 10 Style of type face
J Appl Psychol 16:605-613

Paterson DG and Tinker MA 1936
Studies of typographical factors influencing speed of reading: 12 Printing surface
J Appl Psychol 20:128-131

Paterson DG and Tinker MA 1940
Influence of line widths on eye movements
J Exp Psychol 27:572-577

Paterson DG and Tinker MA 1942
Influence of size of type on eye movements
J Appl Psychol 26:227-230

Paterson DG and Tinker MA 1943
Eye movements in reading type sizes in optimal widths
J Ed Psychol 34:547-551

Paterson DG and Tinker MA 1944
Eye movements in reading optimal and non-optimal typography
J Exp Psychol 34:80-83

Payne DE 1967
Readability of typewritten material: proportional versus standard spacing
J Typog Res 1:125-136

Poulton EC 1967
Searching for newspaper headlines printed in capitals or lower case letters
J Appl Psychol 51:417-425

Poulton EC 1969
Asymmetrical transfer in reading texts produced by teleprinter and by typewriter
J Appl Psychol 53:244-249

Poulton EC and Brown CH 1968
Rate of comprehension of an existing teleprinter output and of possible alternatives
J Appl Psychol 52:16-21

Powers S 1962
The effect of three typesetting styles on the speed of reading newspaper content
Unpub master's thesis U Florida

Robinson DO, Abbamonte M and Evans H 1971
Why serifs are important: the perception of small print
Visible Language 5:353-359

Shaw A 1969
Print for partial sight: a research project
Library Association

Smith F, Lott D and Cronnel B 1969
The effect of type size and case alteration on word identification
Am J Psychol 82:248-253

Spencer H and Shaw A 1971
Letter spacing and legibility
Br Printer 84:84-86

Spencer H, Reynolds L and Coe B 1973
A comparision of the effectiveness of selected typographic variations
Royal College of Art, Readability of Print Research Unit

Spencer H, Reynolds L and Coe B 1973
A report on the relative legibility of alternative letter faces
Royal College of Art, Readability of Print Research Unit

Spencer H, Reynolds L and Coe B 1974
Typographic coding in lists and bibliographies
Appl Ergonomics 5:136-141

Telingater SB 1968
The standardization of alphabetic graphemes
J Typog Res 2:233-240

Themerson S 1965
A well-justified postscript: typographical topography
Penrose Annual 58:334-343

Tinker MA 1957
The effect of curved text upon readability of print
J Appl Psychol 41:218-221

Wiggins RH 1967
Effects on three typographical variables on speed of reading
J Typog Res 1:5-18

7.4 Non-prose setting

The design of forms, tables, mathematical notation, bibliographies, type on maps and labels: these are non-prose settings. Many of these problems are quite new: government forms belong to our own century, and do not have a history of craft experience to guide the designer or typographer. This is a challenge to typographers and researchers who have too often clung to the simpler problems of continuous prose.

Bartz BS 1969
Search: an approach to cartographic type legibility measurement
J Typog Res 3:387-398

Bartz BS 1969
Type variation and the problem of cartographic type legibility
J Typog Res 3:127-144

Bartz BS 1970
An analysis of the typographic legibility literature: assessment of its applicability to cartography
Cartographic J 7:10-16

Bartz BS 1970
Experimental use of the search task in an analysis of type legibility in cartography
J Typog Res 4:147-167

Black CE 1964
What you and your typist should know about typing mathematics
STWP Rev 11:8-11

Chaundy TW 1970
Printing for mathematics: aids for authors and rules for compositors and readers at the University Press Oxford
Oxford U Pr

Copland DR 1974
Typographic size control for cartographers
Cartographic J 11:91-93

Crocker WT 1964
Type for maps
Cartography 5:95-100

Dennis I 1975
The design and experimental testing of a hospital drug labelling system
Prog Learning & Ed Tech 12:88-94

Foster JJ and Kirkland W 1971
Experimental studies of map typography
Bull Soc of Univ Cartographers (Autumn) 40-45

Fowler GH 1969
Typing topics I and II
O & M Bul 24:124-129, 212-221

Great Britain, Civil Service Dept Management Services Division 1972
Design of forms in government departments
HMSO

Hartley J, Timson SJ and Burnhill P 1973
Research in brief: subjective preference and retrieval of information from reference material
Visible Language 7:167-170

Humbert C 1973
Label design
Thames and Hudson

Keates JS 1958
The use of type in cartography
Surveying and mapping 75-76

Kernighan BW and Cherry LL 1975
A system for typesetting mathematics
Communications of the Assoc for Computing Machinery 18:151-157

Map design and typography 1964
Monotype Recorder 43:42-52

Poulton EC 1969
Skimming lists of food ingredients printed in different brightness contrasts
J Appl Psychol 53:498-500

Poulton EC 1969
Skimming lists of food ingredients printed in different sizes
J Appl Psychol 53:55-58

Spencer H 1952
Design in business printing
Sylvan Pr

Spencer H, Reynolds L and Coe B 1975
Spatial and typographic coding with bibliographic entries
Prog Learning & Ed Tech 12:95-101

Spencer H and Spencer M 1975
The book of numbers
Latimer

Stringer P 1974
A use of repertory grid measures for evaluating map formats
Br J Psychol 65:23-34

Swanson E 1971
Mathematics into type
American Mathematical Society

Tinker MA 1960
Legibility of mathematical tables
J Appl Psychol 44:83-87

Vardaman PB 1971
Forms for better communication
New York, Van Nostrand

Wendt D 1972
On effects of indentation and underlining in reference work
Visible Language 6:161-171

Wright P 1975
Forms of complaint
New Behaviour 1:206-209

Wright P and Barnard P 1975
'Just fill in this form': a review for designers
Appl Ergonomics 6:213-220

Wilcock B
Problems in the design and scientific and technical journals
Presentation of Technical Information
Discussion Group paper 30

7.5 Newspaper design

Newspaper typography has an excellent literature: Evans, Frayman, Hutt and Sellars are quite outstanding. The large page size, multiple columns, headlines and other devices enable the reader to find and select the items that interest him. Special type faces are used which stand up to long machine runs, and are specially adapted to the short lines and small type size. The use of rules, white space, photographs and layout is also most impressive. Designers of instructional material may find some of their problems (such as, allowing the learner to make the choices that suit him) are better solved by newspapers and magazines than by traditional book publishers. The slogan 'typography as communication' really comes alive in newspaper design.

Arnold EC 1969
Modern newspaper design
New York, Harper & Row

Baynes K 1971
Scoop, scandal and strife: a study of photography in newspapers
Lund Humphries

Collins J 1975
Journalism and design: a marriage can be arranged
Penrose Annual 68:37-62

Davenport JS and Smith SA 1965
The effect of hyphenation, justification and type size in newspaper readability
Journalism Q 42:387

Evans H 1972-6
Editing and design: a five-volume manual of English, typography and layout
Bk 1 Newsman's English
Bk 2 Handling newspaper text
Bk 3 News headlines
Bk 4 Picture editing (in press)
Bk 5 Newspaper design
Heinemann

Frayman H, Griffiths D and Chippindale C 1975
Into print: a guide to publishing non-commercial newspapers and magazines
English Universities Pr

Hutt A 1967
Newspaper design 2nd ed
Oxford U Pr

Hutt A 1973
The changing newspaper: typographic trends in Britain and America 1622-1972
Gordon Fraser Gallery

Looseley AE 1970
The business of photojournalism
Focal Pr

McLean R 1969
Magazine design
Oxford U Pr

Poulton EC 1967
Searching for newspaper headlines printed in capitals or lower case letters
J Appl Psychol 51:417-425

Powers S 1962
The effect of three typesetting styles on the speed of reading newspaper content
Unpub master's thesis U Florida

Sellers L 1968
The simple subs book: a manual for sub-editors (and would-be sub-editors) on newspapers, trade and house journals
Pergamon

Wills FH 1971
Fundamentals of layout for newspaper and ma[illegible]e advertising for page design of publications a[illegible]or brochures
New York, Dover

7.6 Print technology

'Print anything on anything' is the claim – though we may not often want to print on fried eggs (! – a xerography demonstration). Still, as mentioned before, the typographer is now released from many mechanical constraints and can face more squarely the needs of the reader. This makes him a communicator – but he still needs to keep track of the technology. This section lists a few useful sources, but naturally trade magazines and expert consultants must be consulted for really up-to-date information.

Ammonds CC 1970
Printing: basic science
Pergamon

Banks WH ed
Advances in printing science and technology
v 3 Halftone printing 1964
v 4 Paper in the printing process 1967
v 5 Inks, plates and print quality 1969
v 6 Recent developments in graphic arts research 1971
Pergamon Pr

Barnard M 1975
Computers and the printing industry
Nature 257:554-558

Barnett MP 1965
Computer typesetting: experiments and prospects
Cambridge, Mass. MIT Pr

Burke C 1974
Printing it!
New York, Wingbow Pr

Clowes W 1963
A guide to printing
Heinemann

Durrant WR, Whitworth RE and Meacock CW 1973
Machine printing
Focal Pr

Goldring M 1966
Can the typographer assist printing technology?
Institute of Printing Bulletin 12

Goldring M 1966
Rational typographic design
in Advances in computer typesetting
Institute of Printing

Goldring M 1968
The functional relationship between typographers and keyboard operators
Printing Technology 12:7-9

Hague CW 1957
Printing and allied arts
Milwaukee, Bruce

Harrison JT 1964
Problems involved in the graphic reproduction of mixed scripts
J Documentation 20:76-86

Marcus A 1971
A prototype computerized page-design system
Visible Language 5:197-210

Martin AG 1972
Finishing processes in printing
Focal Pr

Moran J ed 1974
Printing in the 20th century: a Penrose anthology
Northwood

Morton A 1969
Mechanical composition
Pergamon

Phillips A 1968
Computer peripherals and typesetting
HMSO

Twyman ML 1970
Lithography 1800-1950: the techniques of drawing on stone in England and Wales and their application in works of topography
Oxford U Pr

Twyman ML 1970
Printing from 1770-1970
Eyre & Spottiswoode

Warford HS 1971
Design for print production
Focal Pr

Woolridge D 1972
Letter assembly in printing
Focal Pr

Young LC 1973
Materials in printing processes
Focal Pr

7.7 Letterforms

This section contains references on the design of alphabets, and on calligraphy.

With the advent of cold composition the ancient skill of calligraphy is once again a practical tool as well as a delightful art. Decorative calligraphy reaches the status of high art in Japan and in the Islamic culture, but is almost a lost skill in the West. A good deal of rethinking will be needed to organise calligraphy for the needs of the scientific/industrial West: maybe calligraphy for mathematics texts is a better notion than calligraphy for poetry?

Also in this section are some historical sources on writing, and some elementary introductions to the main non-Roman languages of the present day. There are a large number of non-Roman scripts alive today, many more than are listed here. The growth of nationalism and the disintegration of the British Empire has utterly destroyed the chance of an international language – though English is still spoken by more people than any other language, and the Roman alphabet by far the most widely used. Apparently we shall continue to live in a world which has hundreds of languages and dozens of different scripts competing in the market-place.

There is virtually no legibility research on non-Roman scripts; this means that Chinese, Japanese, Arabic, Cyrillic and other scripts have to do without the benefits of formal empirical testing. Though this is no great tragedy, yet it would seem a simple matter for the international agencies to set up a small number of centres to offer research services on a contract basis. If we think research does make a difference there is no reason why 'scientific' typography should remain the exclusive property of the Western nations, as it is at present.

Bann S 1969
Concrete poetry and after
London Magazine 9:72-84

Barber EJW 1973
The formal economy of written signs
Visible Language 7:155-166

Basu H 1971
Letterforms as a medium for artistic expression
Visible Language 4:319-330

Bickman G 1743
The universal penman
New York, Dover 1941

Bowler B 1970
The word as image
Studio Vista

Burnhill P, Hartley J, Fraser S and Young M 1975
Writing lines: an exploratory study
Programmed Learning & Ed Tech 12:84-87

Cavanagh A 1946
Lettering and alphabets
New York, Dover 1955

Concrete Poetry 1971
Sound texts, visual texts: catalogue of an exhibition
Amsterdam, Stedelijk

Constantine M 1965
Lettering by modern artists
New York, Museum of Modern Art

Davies NM 1958
Picture writing in ancient Egypt
Oxford U Pr

Degering H 1965
Lettering: modes of writing in Western Europe from antiquity to the eighteenth century 2nd ed
Benn

Diringer D 1968
The alphabet: a key to the history of mankind
3rd ed
Hutchinson

Doblhofer E 1973
Voices in stone: the decipherment of ancient scripts and writings
Paladin

Durer A 1525
On the just shaping of letters
New York, Dover 1965

Follman J, Lowe AJ and Miller W 1971
Graphic variables and reliability and level of essay grades
Am Ed Res J 8:365-373

Gelb IJ 1963
A study of writing 2nd ed
U Chicago Pr

Gordon CH 1971
Forgotten scripts: the story of their decipherment
Penguin

Gordon M 1974
Alphabets and images: inspiration from letter forms
Batsford

Goudy FW 1952
Alphabets and elements of lettering
New York, Dover 1963

Gray N 1972
Lettering as drawing
Oxford U Pr

Gray N 1974
Lettering and society
Visible Language 8:247-260

Haab A and Strocker A 1960
Lettera: a standard book on fine lettering
Tiranti

Harvey M 1975
Lettering design
Bodley Head

International Phonetic Association 1949
Description of the International phonetic alphabet

Jaspert WP, Berry WT and Johnson AF 1970
The encyclopaedia of type faces
Blandford

Jensen H 1970
Sign, symbol and script: an account of man's efforts to write 3rd ed
Allen & Unwin

Johnston E 1917
Writing, illumination and lettering rep 1975
Pitman

Kindersley D 1973
Space craft
Visible Language 7:311-324

Lings M 1976
The Quranic art of calligraphy and illumination
World of Islam Festival Publishing Co

Longyear W 1966
Type and lettering 4th ed
Watson-Guptill

Lotz J 1971
The role of script in describing the languages of the world
Visible Language 5:75-81

Massin 1970
Letter and image
Studio Vista

Mayer P 1968
Framed and shaped writing
Studio International 110-114

Mayer P 1974
Thirteen versions of Ho Chi Minh's poem: Word play
Poetry Review 65:72-79

Morison S 1962
On type designs past and present
Benn

Morison S 1953
Tally of types
Cambridge U Pr 2nd ed 1973

Nakata Y 1973
The art of Japanese calligraphy
New York, Weatherhill

Nesbitt A 1957
The history and technique of lettering
New York, Dover

Ogg O 1971
The 26 letters
New York, Crowell

Ogg O 1953
Three classics of Italian calligraphy
New York, Dover

Perry DK 1952
Speed and accuracy of reading Arabic and Roman numerals
J Appl Psychol 36:346-347

Pitman I 1837
Stenographic sound hand

Pitman Publishing Corp 1946
Basic course in Pitman shorthand

Quong R 1968
Chinese written characters, their wit and wisdom
Boston, Beacon Pr

Read K 1972
Sound writing: George Bernard Shaw and a modern alphabet 1892-1972, written for an exhibition in the library
Reading U Typography Unit

Riddell A 1975
Typewriter art
Joseph

Rosen B 1963
Type and typography: designer's type book
New York, Van Nostrand

Solt ME 1970
Concrete poetry: a world view
Bloomington, Indiana U Pr

Spencer H 1972
Words, words, words
Lund Humphries

Spencer H and Forbes C 1973
New alphabets A to Z
Lund Humphries

Sweet H 1866
A handbook of phonetics
Oxford U Pr

Thompson JES 1972
Maya hieroglyphs without tears
British Museum

Tracy W 1975
Arabic without tears
Penrose Annual 68:121-126

Ullman BL 1963
Ancient writing and its influence
New York, Cooper Square Pubs

Updike DB 1922
Printing types: their history, forms and use
Harvard U Pr

Wieger L 1965
Chinese characters: their origin, etymology, history, classification and significance 2nd ed
New York, Paragon

Wilson JVK 1974
Indo-Sumerian: a new approach to the problems of the Indus script
Oxford U Pr

Zapf H 1970
About alphabets: some marginal notes on type design
Cambridge, Mass. MIT Pr

8 Cartography

'The trouble with Winston is that he's always taking action. He will insist on getting out his maps. In 1914 he got out his map of the Dardanelles, and think where that landed us. After the war he got out his maps of Russia and we were making fools of ourselves in the civil war. When that was over he got out his maps of Greece and Turkey, and that brought my tottering administration to a close.'
Lloyd George on Winston Churchill

Maps are ancient graphic devices: one clay map from Mesopotamia is dated 2,500 BC – earlier than the first musical notation, and later than the first non-pictorial script. These recording devices (and arithmetical notation) were needed by city states, and were invented when men made the change from nomadic life by means of agriculture and the construction of cities. Cartography in the Graeco-Roman civilisation was remarkably sophisticated, as we might expect from the needs of trade and administration. Eratosthenes (c 200 BC), who accurately estimated the earth's circumference, and Ptolemy (c 200 AD) who constructed an excellent world map, stand out as the foremost cartographers of their age. That they were both in their day Librarian of Alexandria was no doubt more than a coincidence: cartography is a synthetic art, and that library was a rare collection of systematised knowledge.

The subsequent history of cartography follows a familiar pattern. Ptolemy's maps were temporarily lost after the destruction of the Library at Alexandria and the collapse of the Western part of the Roman Empire. His works were part of the intellectual treasure brought from Byzantium (Constantinople) to Italy in the fourteenth century. This rediscovery occurred as European nations started the explorations that led to world-wide trade and to the empires which came to include most of mankind. The needs of the navigators and explorers and the growing power of science led to accurate maps of the whole globe and of the heavens: one of the remarkable triumphs of the Enlightenment.

As the scientific/industrial revolution gathered pace cartographers developed special-purpose or 'thematic' maps whose purpose was to display particular sets of scientific or social data. Thrower says 'all the common techniques of thematic cartography in use today had been developed by 1865'. For example, there is the traffic flow map of Ireland by Harness (1837) and the dot map showing the relation of cholera deaths to water sources by Dr Snow (1855). Apart from the development of Isotype (see Neurath's *Gesselschaft und Wirtschaft*, section 4.4) Thrower's claim is broadly correct. The twentieth century has seen the use of new technology (aerial photography, computers) and the start of formal empirical testing. The remarkable use of scientific modes of thought in the Second World War (operational research, task analysis, ergonomics) led directly to the empirical studies which are becoming part of the cartographer's way of thinking and behaving.

The standard of empirical work in cartography is quite respectable, at any rate superior to some of the other sections in this bibliography. This may be because cartography is an established discipline with procedures and methods of scholarship. Often experiments on other kinds of graphic material have been done by workers who were completely ignorant (even contemptuous) of the subtleties of the stimulus material. Not so in cartography, which is one discipline where graphic communicators can occupy regular university posts.

There are several excellent textbooks listed here. My preference goes to Monkhouse and Wilkinson for a general text; Davis and Fitzgerald are good and cheap; Thrower is a sound historical essay with a valuable glossary; Robinson's *The look of maps* is a readable and influential look at the basic issues in map design. It is almost unknown for a modern university to allow conceptual analysis for a thesis, but this work by Robinson shows the value of an occasional ground-clearing exercise. The modern cartographer is concerned with how the reader interprets the map, and how the reader's task may be facilitated or inadvertently hindered. This interest in the reader is typical

of our times and, as explained before, is mainly due to the growth of instructional technology in the Second World War. We have every reason to welcome this attitude and support further work on the map user.

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9.1 Notations, codes and symbols: general

'The history of notation has always been one of continuous experiment and evolution' *Smalley*

Notations, codes, cyphers, symbols, signs: these terms tend to get used in a slack and confused manner, yet we seem to need them to describe certain kinds of special-purpose communication. The distinction between sign and symbol is enough to tax any professional philosopher, so it would be idle for the reader to expect any simple route to conceptual clarity. But a few useful remarks can be made

The notion of a 'sign' is too broad for our purpose here. When Charles Morris says 'Men are the dominant sign-using animals' he means speech, writing, art – just about all conscious forms of human communication. And when my cat's paw is abruptly stopped in mid-swoop by the stripes on a bee he, too, is responding to a sign. Therefore we use the term *symbol* to mean those conventional marks or characters which are meant to convey certain publicly agreed notions. We exclude written ordinary language from this definition, though symbols can be used to stand for words. A *notation* is a system of symbols devised for a particular purpose, for example musical notation. All notations have well-defined rules for construction and for interpretation; such rules allow the symbols to be articulated (connected together) so that complex ideas can be efficiently expressed. Each notation has a domain of application, that is, an arena or subject-matter where the rules apply. In general, the aim of each notation is to improve on ordinary language for some particular purpose.

Like notations, *codes* are invented because of the limitations of ordinary language – but there the resemblance ends. The purpose of a notation is to say something that can hardly be said in ordinary language; but the point of a code is to hide a message that would be all too clear in plain language. Technically, one should distinguish codes from cyphers (codes are lists of words which replace 'plaintext' words whereas cyphers consist of rules for replacing plaintext letters with code numbers or letters) but this kind of technicality is not useful in a bibliography, for all works that deal with codes also deal with cyphers.

The works by Frege and Goodman are the only important essays on notations in modern philosophy. Leibnitz's idea of a universal notation for thought has proved impractical, though artificial intelligence has made the idea less ridiculous than it once seemed. We know now that notations must be specialised, else they face all the problems of complexity of ordinary language, with none of the flexibility needed to accomodate those problems. Ambiguity, vagueness and opacity is the price paid for the flexibility of ordinary language; and restricted application is the price paid for the exactness and tractability of a good notation.

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9.2 Mathematical and logical notations

These are by far the most important notations; collectively they must rank as one of the great inventions of civilised man. For the history of these notations Cajori is a standard source, and Hogben's *Mathematics in the making* is a sound popular introduction. Mathematical notation is one of the four graphic inventions that date back to the start of permanent settlement in cities. (The other three are written language, musical notation and cartography; general illustration is prehistoric and of course the origins of spoken language are unknowable.)

In logic and mathematics we see an intimate relation between notation and thought: the choice of the elementary building blocks makes some expressions simple, and others impossible. Thus a notation is bound to open some doors whilst closing others; this we can see clearly in the work of the logicians Boole, Venn, Frege, Russell and Spencer Brown. Frege is notable for the prominence he gave to the choice of notation, and for the links he made between logic and mathematics. Russell and Whitehead tried to unify mathematics in set theoretic terms, and their work was extended by the French school of Bourbaki. However, the complete unification of mathematics and logic has not yet succeeded so quite a variety of notations continue in use under constant revision and development.

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9.3 Musical notation

It seems that musical notation is almost as old as mathematical notation and owes its origin to the same cause: when men developed agriculture in river valleys and settled in cities they needed ways to record events, property, laws, trading – and they needed a way to pass on their culture. The visual arts are their own record, but music cannot develop without a notation. Prior to a notation simple tunes can be learnt by ear, and that is all a tribal or nomadic race can achieve. But a city can keep records, and this allows the culture to become progressive – that is, one man's work can build upon another's. Evidently writing, notations, maps and other graphic devices are crucial prerequisites for that process of cultural evolution which is so characteristic of civilised man.

Notations do not, however, spring forth fully developed. They have strict rules for construction and interpretation which do restrict the things users can do; but nevertheless innovations are introduced and the notation itself gradually evolves. This process is well documented in Dart's essay on notation in *Grove's Dictionary;* apparently the principle of 'one note, one symbol' is of quite recent origin, yet without this modern version of the staff notation we would scarcely have the great symphonies. Every so often avant-garde musicians feel the notation is too constraining, and they propose innovations – we are going through such a phase now; Cage is useful source for those interested in modern music. The need for widespread agreement on the rules for construction and interpretation is often underestimated by the innovator, yet without such agreement the notation simply cannot function as a vehicle for facilitating the exchange of ideas or (as in music) as a set of instructions for reproducing sounds.

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9.4 Other notations

Of the dozens of other notations only a few are listed here by way of illustration. Chess has the largest literature by far of any game: its subculture is entirely dependent on notation for recording games and positions. Dance and architectural notations are of recent origin, and were much needed. Like music, dance routines can only be passed on by personal experience unless a notation is available. It is remarkable how far ballet developed with such a limitation; though the centralised and demanding ballet training no doubt made sure that basic technique was strictly replicated. Chemistry has a most effective system of notation, which allows one to express chemical reactions in the form of an equation. This notation and the periodic table have been crucial to the modern development of this science; such conceptual tools can be as important as the apparatus in the laboratory. In fact, when we use the term 'discipline' we recognise that there is more to the subject than just a set of results: there are people, problems, procedures, apparatus and conceptual tools which work together in a coordinated way to produce the results we value so much. Most other sciences have notations, though few are as well-documented and important as chemical notation.

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New York, Holt, Rinehart and Winston

9.5 Codes and ciphers

Kahn's book (original hardback edition) is the best single source on the technical and dramatic history of cryptography; it can be unreservedly recommended to non-specialist readers. Naturally, the latest ideas in this field are always under security wrappings, but the principles are quite simple. We can presume that the growth of computer science now makes basic cryptanalysis quite trivial; but also allows for hugely complex encoding algorithms.

One debate that is being conducted in public is the esoteric (but possibly one day vital)

question of decoding communications from 'alien sources'. The problem is that almost none of the standard cryptanalysis procedures can be used on a message generated by non-human entities. The enthusiasts suppose that by starting with basic mathematics and logic a sufficient syntax could be developed to allow the transmission of all other kinds of knowledge. So far, no-one has got such schemes past the blueprint stage: for the state of the art see Sagan.

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9.6 Symbols

Authorities differ on the importance they attach to the creation of visual symbols. Neurath saw a dictionary of symbols as the first step towards an international system of graphic communication (Isotype, section 4). Others take a more relaxed view – if it works, that is enough. No doubt the way symbols are used together to show the message is the most important thing; but let no-one underestimate the difficulty of designing good symbols, and the debt we owe to those designers who have given their lives to this kind of work.

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Recommended reading

Educational technology, instructional psychology and graphic design tend to suffer from shallow roots; they lack a cultural tradition. In these new fields it is possible to collect degrees and diplomas and pass as a professional, and yet be ignorant of many things of material relevance. There is no reason to suppose that the publication of a mere bibliography can by itself eradicate such a situation: but it may have some beneficial influence. Here I list 32 books and papers which should be included in the reading list of courses on graphic communication and allied topics. This is, of course, a personal selection. Detailed empirical studies (the main body of this bibliography) are not listed here; instead I have listed some works of broad scope which (hopefully) may provide that basic understanding without which no empirical study can be sensibly interpreted. This has been a main theme of the bibliography: that formal experiments do not – cannot – supplant the experiential knowledge of the skilled practitioner. Rather, the experience and the criticism of the practitioner is needed to give direction and coherence to the formal experiments.

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